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USE OF WEB-BASED LESSONS OF STATISTICAL CONCEPTS WITH GRAPHICS
AND ANIMATIONS TO ENHANCE THE EFFECTIVENESS OF LEARNING

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Engineering

By

LAVANYA PILLALA
B.Tech, J.N.T.U, 2007

2010
Wright State University

WRIGHT STATE UNIVERSITY
SCHOOL OF GRADUATE STUDIES

February 19, 2010

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY
SUPERVISION BY Lavanya Pillala ENTITLED Use Of Web-Based Lessons Of
Statistical Concepts With Graphics And Animation To Enhance The Effectiveness Of
Learning BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF Master of Science in Engineering.

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ABSTRACT

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Use of Web-Based Lessons of Statistical Concepts with Graphics and Animation to Enhance the Effectiveness of Learning.

Statistics is of critical importance to engineers. However, many engineering students struggle to grasp the meaning of statistical concepts and the idiosyncrasies of statistical methodologies. Because of this problem, instructors of statistics are constantly searching for better ways to help students understand statistical concepts. The goal of this project is to design and develop web-based lessons that use graphics and animations to enhance the effectiveness of students' learning of statistical concepts.

Lessons of three important statistical concepts have been developed for this thesis - normal distribution, central limit theorem and confidence & tolerance intervals - following well-recognized instructional design development processes and principles. A between-subject experiment was conducted with 20 freshmen engineering students as research participants. The experimental results suggest that compared to the traditional instruction method, the web-based lessons can significantly enhance students' learning outcomes (by 29.8%) and their satisfaction with the learning process (by 19.2%).

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I.INTRODUCTION

1.1 What is Statistics and Its Importance to Engineering

Statistics is a field of study used to analyze and interpret data. It is a discipline concerned with design of experiments and data collection. Collected data is analyzed and organized in an understandable manner so that conclusions can be drawn from the data.

Although statistics is often incorporated as a part of the mathematics curriculum, statistics and mathematics are two different fields. It is often understood by students that mathematical solutions are accurately obtained if the assumptions made are valid (Pereira-Mendoza, 2002) and mathematics works on numbers most of the time (Cobb & Moore, 1997). In statistics on the other hand results are not known until a conclusion is drawn and this conclusion may or may not be reliable (DeMas, 2004; Greer, 2000). Numbers in statistics are often termed as experimental data and these numbers are used for data analysis to draw a conclusion about the data.

Statistics is of particular importance to engineering. Many engineering tasks involve designing experiments and collecting data. After data is collected, engineers must be able to analyze it and draw meaningful conclusions about the task using knowledge of statistics. For example, engineers perform various experiments to examine the behavior of structures under stress and the point at which they fail. During the experiments, an

engineer collects data that is used to estimate the quality of the structure and the effectiveness of the engineering design that created it.

1.2 Challenges in Statistics Education

Despite the importance of statistics in engineering, there have often been misconceptions and errors in understanding statistical concepts (Garfield & Ahlgren, 1988; Shaughnessy, 1992; Garfield, 1995). Shaughnessy (1992) summarized the research conducted by psychologists to study the extent of student's perception and retrieval of statistics concepts. A focus of this study was to identify the topics that were most problematic to students. Three similar studies were conducted by Batanero, Estepa, Godino, and Green (1996), Yu and Behrens (1995), and Falk and Greenbaum (1995). Those studies suggested three important topics that are commonly misunderstood or wrongly interpreted by students: contingency tables, sampling distributions and significance tests.

Groth and Bergner (2005) examined the use of metaphors as a way to reveal students' understanding of statistical concepts and were disappointed to note that students who have completed a course in statistics often have limited or incorrect understanding of the idea of what exactly 'sample' means in statistics. According to Cohen and Firestone (1939), "a lecture is a process whereby the notes of the professor becomes the notes of the student without passing through the minds of either" (p. 714). Merely listening to a professor's speaking about a topic does not help student's learning of the topic. Even if a professor is perfect with his/her job of teaching he/she may not be able to improve the students' understanding levels. Previous studies suggested that instruction materials

should be carefully chosen such that students' understanding and reasoning of statistical concepts can be improved to some extent (Garfield & Benzvi, 2007). While teaching statistics, instructors have to consider encouraging students to think about statistics as not simply working with numbers but making students understand that the data given to them for analysis is used to draw a conclusion about an issue or a question (Cobb, 1999; Gal & Garfield, 1997).

1.3 Widely Recognized Needs for Improving Statistical Education

The International Association for Statistics Education (IASE) 'seeks to promote, support and improve statistical education at all levels everywhere around the world. It is the international umbrella organization for statistics education. It fosters international cooperation, and stimulates discussion and research'. This website can be accessed at, <http://www.stat.auckland.ac.nz/~iase/>. Statistics Education Research Journal (SERJ) is an electronic journal which was implemented as a part of IASE whose objective is to improve research-based knowledge among students. There have also been active organizations and conferences devoted to improving statistics teaching methods such as – International Group for the Psychology of Mathematics Education (PME, <http://igpme.org>), The Mathematics Education Research Group of Australasia (MERGA, <http://www.merga.net.au>), The International Statistical Institute (ISI, <http://isi.cbs.nl>), The International Conference on the Teaching Statistics (ICOTS, <http://www.stat.auckland.ac.nz/iase/conferences.php>) and The International Congress on Mathematics Education meetings (ICME, <http://www.mathunion.org/ICMI>) to name a

few. Numerous presentations and publications from these conferences reflect the fact that there is a widely recognized need for improving statistical education.

In addition, graduate students are completing dissertations in various departments that are related to teaching and learning statistics. Over 44 doctoral dissertations have been reported since 2000 (see <http://www.stat.auckland.ac.nz/iasedissert>). All these research activities and effort to improve statistics education reveal the fact that the aim to improve statistics knowledge among students is still unattained and the students' perception and reasoning about statistics education have been quite unsatisfactory. Even with the best statistics instruction, not only students but also even experienced researchers may still have many misconceptions and wrong perceptions about statistics (Garfield, 1995).

1.4 Limitations with Traditional Statistics Instruction Methods

Statistics is considered a difficult subject by students because of a need to work with lots of formulae (Ragasa, 2008). Ziegenhagen and Hardle (2007) from Humboldt-University, Berlin wanted to examine the reasons for low scores in statistics courses using a traditional teaching method. Students in their study commented that the traditional course curriculum was too formal with too much mathematics and too much content that is covered hastily.

Another study which examined the level of students' statistical knowledge revealed the fact that many students lack a true understanding of statistics, they are taught to use techniques which they do not understand and they do not realize that scientists who

use statistics techniques to solve real world problems have different perspectives on statistics – (Oosthuizen, 1990). The languages used in teaching statistics can be unintelligible even to scientists in other disciplines who want to use statistics in their research and to know why, when, and how statistics can be used.

The Program for International Student Assessment (PISA) study aims to improve educational methods by assessing school children's performance around the world. A scenario has recently been discovered at Johannes Kepler University, Linz, Austria, which uses a traditional method of teaching. Some of the original PISA exercises were given to students on the statistics course to check their basic mathematical knowledge. As Duller (2004, 2007a) reported, the results were unsatisfactory and have even deteriorated since. In fact, exam grades have not improved although the standard of exams has been lowered over the last 10 years.

These studies shows that the instruction materials should be carefully designed along with the help of few technological tools and these activities might help improve student reasoning and understanding over a period of time (Ben-Zvi, 2000). These studies also suggest few sequences of activities which can help students in developing ideas of important concepts and offer implications for the types of instructional activities and technological tools that may facilitate students learning and reasoning.

1.5 Objectives of the Thesis and Its Significance

To overcome the limitations mentioned above in current statistics teaching methods, the objective of this thesis is to design a web-based course using graphics and

animations to enhance students' learning of statistical concepts and bring them greater satisfaction in the learning process.

Graphics and animations are particularly capable of attracting learners' attention and facilitating understanding of abstract concepts, both of which are important in teaching statistics. The web-based lessons can be easily accessed by students using any standard web browser. Previous studies suggest that compared to the traditional form of teaching, web-based teaching along with an integration of proper technological tools can lead to better understanding of statistical concepts (Ben-Zvi, 2000).

This research has proposed a web-based statistics course supported by visualization and animations which can facilitate more effective learning of statistical concepts. Experimental results have demonstrated the advantages of the web-based course over the traditional teaching method in terms of improved effectiveness and students' satisfaction with the learning process. Graphics and animations have been developed in the project, which have been shown empirically to enhance understanding of statistical concepts.

1.6 Organization of the Thesis

The organization of this thesis is as follows. Chapter 2 reviews related research on students' learning styles, statistical instruction methods, information technologies applied in statistical education, instructional design and development process, and principles of instructional design. In Chapter 3, a conceptual model of the web-based course is proposed, and two hypotheses are derived from the conceptual model. Chapter 4 describes an experiment conducted to test the proposed hypotheses and the analysis of

experiment results. At last, in Chapter 5, conclusions and limitations of this research are discussed.

II. LITERATURE REVIEW

In this chapter related research on students' learning styles, statistical instruction methods, information technologies applied in statistics education, instructional design and development process, and principles of instructional design are reviewed.

2.1 Students' Learning Styles

Students follow different learning styles. According to Downes (2008), each individual may have different ways of combining senses. Students' learning styles are based on their preferences about learning a concept and how they use their senses to study a concept. Generally speaking, learners can be categorized into three types: visual learners, auditory learners and tactile/kinesthetic learners (Bogod, 1998). These learning styles as explained by Bogod (1998) are discussed in the following three paragraphs.

Visual learners have to see the instructors' body languages and facial expressions to fully understand the content of a lesson. They may think well with the help of pictures and learn best from visual displays including diagrams, illustrated text books, videos, flipcharts and hand-outs. During a lecture or classroom discussion, visual learners often prefer to take detailed notes in order to absorb information (Bogod, 1998).

Auditory learners learn better through listening to instructor's lectures, discussions and through brain storming sessions. They listen to what other have to say

and understand the meanings of speech through speakers' tone, pitch, speed and other nuances of the voice. Written material may have little sense to auditory learners until it is heard. These learners often benefit from reading text aloud or using a tape recorder.

Tactile/Kinesthetic Learners learn through moving around and practically applying what is taught to them in class. They learn best through active participation and by exploring the physical world around them. They may find it hard to sit still for long periods and may become distracted by their need for activity and exploration (Bogod, 1998).

Difficulties in student learning with respect to statistics is the major concern of this research because it would be easier for an instructor to design the instruction materials as per students' needs if students' learning preferences and difficulties they face are known. However, instruction materials should be designed in such a way that it is understandable to all types of learners. Marzano (1998) found that "graphic and tactile representations of the subject matter has noticeable effects on learning outcomes, regardless of any attempt to match them with learners' modalities."

A survey of students' grades in statistics and professors' views about student performance would be a good way to assess the effectiveness of student's learning styles. Based on the survey we can understand the pros and cons of the learning styles followed by students. Schutz, Drogosz, White, and Distefano (1998) systematically studied the effect of motivation on students' performance in a statistic course. They broadly defined

motivation using the learning beliefs, elaboration, and test anxiety scales of the Motivated Strategies for Learning Questionnaire (MSLQ) and included whether students spent additional time using alternative learning strategies such as relating the material studies to other coursework, visualization, and the development of analogies. Students who performed well used the traditional methods of reading, highlighting, memorization, and working sample problems and they also sought out tutoring, read other textbooks related to statistics, completed programmed instructional texts, used visualization, rewrote notes into their own words, and engaged in regular daily studying. Students who performed poorly in the class used the traditional studying methods but did nothing more.

2.2 Statistical Instruction Methods

The most common form of teaching method uses a black or white board, or a set of digital slides that are either in PowerPoint or Adobe PDF format (Hardle & Klinke, 2007). A main advantage of using slides is that one can easily add links to data sources and include low-level dynamic content. Some instructors, however, carry out teaching as a process where they explain the topics to be taught without use of digital slides.

Galloway (2000) mentioned that some teachers are creating instruction materials that involve all sorts of graphics to enhance traditional instruction methods from PowerPoint slides to web pages. The reason why other instructors are not employing such techniques in their teaching process might be because it is very time-consuming and sometimes teachers may not know how to create or employ graphics of higher levels, or searching for the right graphic or imagery that fulfills a specific purpose can be difficult.

They might not want to devote their personal resources to higher graphic applications. Certainly, not everyone has the skills to draw or create graphics from scratch. As people get more experience with the imagery throughout our environment they can actually get better at “interpretation of visual media” (Tyner, 1998, p. 107).

Graphics can affect the way learners understand the material. Teachers are creating more and more media products that involve or perhaps should involve graphics. All sorts of graphics can be used to adorn and enhance media products from PowerPoint slide shows to web pages.

It is important to understand how students make use of the instruction materials of the current teaching method and their problems with grasping them. In a study by Ziegenhagen and Hardle (2007) it was found out that students’ feel that the traditional methods of statistics teaching are too formal and cover too much content at a fast speed. Visualization can be an effective way to overcome these issues (Nolan & Lang, 2007). One way is to design an alternative website or webpage specifically accessed by students in their courses where they can explore and find an answer to their questions. With this approach, instructors do not need to spend much time teaching concepts that are easily understood by students. Electronic teaching materials have been developed recently, and by distributing the material electronically students will have a chance to concentrate on lectures rather than copying the contents of the slides. Various web-based learning environments have also been developed recently. Technology-based instruction methods will be discussed in more detail in section 2.3.

2.3 Information Technologies Applied in Statistics Education

One of the major areas of current interest in statistics education is the role information technologies such as computers, graphing calculators, software, and internet can play in helping students develop statistical literacy and reasoning. This section will focus on discussing how internet and virtual environment have been applied in statistical education.

2.3.1 Benefits of Using Internet in Instruction

Various resources are currently available via the World Wide Web to help support statistics instruction. More and more instructors are providing course materials to their students through websites. The guidelines for assessment and instruction in statistics education (GAISE, 2005) project noted that the biggest change in the way statistics is taught these days is through increasing use of technology.

Internet is widely used by students for accessing information. It is easy for students to access any kind of information with new updates using internet. Neuroscientists comment that ‘Internet beats books for improving the mature mind’. Research suggests that browsing the internet is better than reading books for boosting the brain power of middle-aged and older adults. ‘Brain scans show that going online stimulated larger parts of the brain than the relatively passive activity of reading a novel or non-fiction book.’ – (Alleyne, 2008). Through the increasing use of technological tools students now might get bored easily with the textbooks and there is also a chance that they ignore instructors’ lectures – (Galloway, 2000).

2.3.2 Benefits of Graphics and Animations in Instruction

Visualization can play a significant role in enhancing students' ability to study random processes and statistical concepts (Lane & Peres, 2006; Lane & Tang, 2000; Mills, 2004). Visual aids can make presentations more interesting, more dynamic, and more effective — if they are used appropriately (Laskowski, 1998). The main purpose of visualization is to 'reinforce stated facts, aid the understanding of ideas, clarify relationships of physical layouts and introduce the audience to a new topic area.' Multimedia is a type of visual aid used to create a powerful and effective presentation (Interactive Training Technologies, 2000).

DelMas, Garfield and Chance (2004) developed animations to explain the Sampling Distribution and implemented them in a class and data was collected from three different institutions. Based on this study it was found that the student performance improved positively. Lunsford, Rowell and Espy (2006) replicated this study in a different type of undergraduate course and found similar results. Lane and Tang (2000) compared the effectiveness of animations for teaching statistical concepts to the effectiveness of a textbook, while Aberson, Berger, Healy, Kyle and Romero (2000) studied the impact of a web-based, interactive tutorial used to present the sampling distribution of the mean on student learning.

There are many resources on the internet to not only support but also to encourage graphic development in web pages (Sharp & Sharp, 1997). Graphics can help students better relate to and understand information. PowerPoint presentations, unfortunately, are often designed exclusively with text. Graphics, on the other hand, can include

information not discussed in the text, although it is related to the text discussion. Sometimes they contain information stated in the text, but present it in a more visual form. At other times, they may contain a mixture of information from the text and information not in the text, making connections apparent. Whatever their content, graphics displays have been found to improve students' comprehension (Roe, Stoodt & Burns, 1998, p. 185).

The purposes of graphics in instruction are to attract learner attention, direct learner action, represent concrete and abstract concepts, and simplify complex information (Emery, 1993, p. 21). Students understand concepts more clearly when graphics are used (Alesandri, 1984; Emery, 1993; Levie, 1984). Many studies that compared lessons that used text alone to teach content and lessons that added relevant visuals to the text have shown that the versions with the graphics can improve learning” (Clark, August 2003, p. 2).

Students at Empire High School in Vail, Arizona, have given up traditional textbooks completely to be replaced by electronic media according to Wired News, 2005. Electronic media has long been packaged with traditional textbooks (Turner & Land, 1988; Roblyer, 1999), and, so-called electronic textbooks have increasingly served as modern alternatives to print media (Desberg & Fisher, 1998; Galloway, 2003). Teachers are learning to build web sites to support their own teaching with graphics and for these clip art can be highly desired elements.

Reiber (1990) suggested that animation can serve three functions in instruction: attention-gaining, presentation, and practice. Rieber (1990) pointed out that attention-

gaining is one of the three major functions of animation. Animation helps in decreasing the time necessary to retrieve information from long-term memory and then subsequently reconstruct it in short-term memory - (Rieber, Boyce & Assad, 1990, p. 50). Similarly, Hannafin and Peck (1988) suggested that animations can help emphasize important information by providing contrasts with a static background.

Animation acts as an aid in dual coding. According to dual coding theory, learning is enhanced when information is coded both visually and verbally. The chances of retrieval are doubled when information is dually coded because learners have two ways to retrieve the information. This prediction has been used to explain the superiority of pictures to words in recalling information (Kobayashi, 1986; Paivio, 1991; Paivio & Caspo, 1973; Rieber, 1996). Animation, due to its unique dynamic qualities, is more likely to be dually coded "deeper" and "harder" into the long-term memory than are static graphics (Lin, 2001, p. 20).

However, graphics must be used only in situations where its use is appropriate. Harp and Mayer (1998) found that visuals and text that were topically related to the lesson but extraneous to the lesson goal depressed learning. They include that, "Many are not using graphics effectively. Designers need to think about 'the content of the lesson, instructional goal that has to be achieved, target audience, method of delivery, and the best graphic to use,'" (Materi, 2003, p. 7). As per the instructional objectives of the project, carefully designed and properly executed graphics were important for product's instructional success. However, research on visualization design indicates that for graphic or animation to be an effective teaching tool, students' interaction with it is has to be carefully structured (Lane & Peres, 2006).

2.3.3 Web-Based Statistical Instruction

Web-based lessons include two types of instructions: purely text-based lessons and lessons with graphics and animations.

2.3.3.1 Text-Based Lessons

Text-based lessons are a type of web-based instruction for teaching statistics. These web-based courses are designed in a purely text environment and some of them include static graphics to teach statistics concepts. Animations are not included in this type of web course. Two text-based lessons - hyperstat and stockburger's web-based course - are first discussed in this subsection. These two lessons resemble traditional statistical textbooks in explaining statistical concepts. Then, the following paragraphs give a brief overview of some web-based courses for five statistical concepts individually. These five statistical concepts are chosen by a SME (Subject Matter Expert) for this project.

Hyperstat

Lane (WWW, 2010) spent 14 years (from 1993 to 2007) developing an online statistics textbook called Hyperstat (<http://davidmlane.com/hyperstat/index.html>). It is accessible through any standard web browser. Hyperstat acts as an introductory statistics textbook and online tutorial for statistical courses. This website has links to various other sites that can be helpful to students during their learning process, such as Statistics Solutions Inc. which serves graduate students and researchers by producing and delivering expert data analysis, clear sample size justification, comprehensible results, and ongoing support with fast response time and low cost in the statistical consulting

field. Hyperstat also has hyperlinks to statistics textbooks, ways to improve student learning, statistics concepts, and its applications, as illustrated in Figure 1. Table of contents is displayed on the left most corner of the webpage.


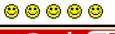
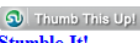


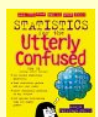

HyperStat Online Statistics Textbook	Related Material	Books
<p>RVLS Home Glossary Free Statistical Analysis Tools Instructional Demos Exercises and Problems Statistics Help Privacy policy</p> <p>Search HyperStat Using the Customized Search (below)</p> <p>Add this search to your site.</p> <p>Google Custom Search <input type="text"/> <input type="button" value="Search"/></p> <p>Create your own Custom Search Engine</p> <p> Gadgets powered by Google</p> <ol style="list-style-type: none"> 1. Introduction to Statistics 2. Describing Univariate Data 3. Describing Bivariate Data 4. Introduction to Probability (elementary) 5. Normal Distribution 6. Sampling Distributions 7. Point Estimation 8. Confidence Intervals 9. The Logic of Hypothesis Testing 10. Testing Hypotheses with Standard Errors 11. Power 12. Introduction to Between-Subjects ANOVA 13. Factorial Between-Subjects ANOVA 14. Within-Subjects/Repeated Measures ANOVA 15. Prediction 16. Chi Square 17. Distribution-Free Tests 18. Measuring Effect Size 	<p> Ads by Google</p> <p>Online Statistics Tutors Tutoring & Homework Help 24/7 by College Statistics Professors www.ASAPTutor.com</p> <p>Colorado State University distance graduate statistic courses MS degree and certificates www.stat.colostate.edu</p> <p>10 Hour Probability DVD Master Probability and Statistics painlessly. Learn by examples. www.MathTutorDVD.com</p> <p>Statistics Solutions, Inc. Research Proposal and Statistics Help for Grad Students Free Consultation 877-437-8622 www.StatisticsSolutions.com</p> <p></p> <p>Follow this link to statistics jokes humor sites.</p> 	<p>Textbook Expert Reviews, Bestsellers & More. Find Your Next Book at Target. www.Target.com/Books</p> <p></p> <p>Statistics for the Utterly Confused by Lloyd Jaisingh</p> <p>A good introductory statistics book, somewhat more elementary than HyperStat.</p>  <p>The Visual Display of Quantitative Information by Edward R. Tufte</p> <p>This book is "must" reading for anyone creating or interpreting graphs. Beautifully done.</p> 

Figure 1: A Screenshot of Hyperstat's Main-Page with Table of Contents Column and Hyperlinks

In Hyperstat, the user can click on the link he/she is interested in reading. Each topic includes its definition along with some examples. The explanation is entirely text-based. The user has access to links that support topic content where he/she can further improve his/her knowledge about the topic of interest by clicking on the hyperlinks, as illustrated in Figure 2. Hyperstat also provides some exercises to test students' knowledge and the extent to which they were able to grasp the concepts. The glossary

page contains definitions of frequently used terms that students will come across while reading the tutorial in an alphabetical order, as shown in Figure 3.

[RVLS home](#) > [HyperStat Online](#) > [Chapter 1: Introduction](#)

Variable (2 of 2) [Prev](#)

[Next Section: Parameters](#)

For example, consider a hypothetical experiment on the effect of drinking alcohol on reaction time: Subjects drank either water, one beer, three beers, or six beers and then had their reaction times to the onset of a stimulus measured. The independent variable would be the number of beers drunk (0, 1, 3, or 6) and the dependent variable would be reaction time.

Continuous and Discrete
Some variables (such as reaction time) are measured on a [continuous](#) scale. There is an infinite number of possible values these variables can take on. Other variables can only take on a limited number of values. For example, if a dependent variable were a subject's rating on a five-point scale where only the values 1, 2, 3, 4, and 5 were allowed, then only five possible values could occur. Such variables are called "[discrete](#)" variables.

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Visualizing Data
A classic book by W. S. Cleveland. Approaches, methods, many examples.
[www.hobart.com](#)

Figure 2: A Screenshot of Hyperstat's Explanation of a User Selected Statistical Concept

[RVLS home](#) > [HyperStat Online](#) > [Glossary](#)

Glossary

A-C [D-F](#) [G-I](#) [J-L](#) [M-O](#) [P-R](#) [S-U](#) [V-Z](#)

[alternative hypothesis](#)
[Analysis of variance](#)
[Bar graph](#)
[Between-subjects variable](#)
[Bias](#)
[Biased sample](#)
[Bimodal distribution](#)
[Binomial distribution](#)
[Box plot](#)
[Carryover effects](#)
[Categorical variable](#)
[Central tendency](#)
[Chi square distribution](#)
[Chi square independence test](#)
[Coefficient](#)
[Conditional probability](#)
[Confidence interval](#)
[Confounding](#)
[Consistency](#)
[Contingency table](#)
[Continuous variable](#)
[Correction for continuity](#)
[Correlation](#)
[Counterbalancing](#)
[Critical value](#)
[Criterion variable](#)
[Cumulative distribution](#)

A-C [D-F](#) [G-I](#) [J-L](#) [M-O](#) [P-R](#) [S-U](#) [V-Z](#)

Alternative Hypothesis

In [hypothesis testing](#), the null [hypothesis](#) and an alternative hypothesis are put forward. If the data are sufficiently strong to reject the null hypothesis, then the null hypothesis is rejected in favor of an alternative hypothesis. For instance, if the null hypothesis were that $\mu_1 = \mu_2$ then the alternative hypothesis (for a [two-tailed test](#)) would be $\mu_1 \neq \mu_2$.

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Figure 3: A Screenshot of Hyperstat's Glossary Page

Web-Based Statistical Course by Stockburger

Stockburger (1998) developed a text-based website focusing on introductory statistics concepts along with some models and their applications. This website can be accessed at, <http://www.psychstat.missouristate.edu/introbook/sbk00.htm>. The material presented in the statistical concepts pages represents over twenty years of experience in teaching. Stockburger developed this website in order to overcome the high textbook prices and to fulfill his desire to customize course material for his own needs. Since 1996 the web text and associated exercises has been updated until 1998. While the text-based website is the first edition, two other editions were developed with changes that include more interactive exercises, and animated examples of the use of statistical packages. A third edition was published by Atomic dog publishing in spring, 2007 which was only for private use. Figure 4 is a screenshot of Stockburger's website main page. Table of contents for introductory statistics concepts are placed on the left most column of the webpage, as shown in Figure 4.

[Introductory Statistics: Concepts, Models, and Applications by David W. Stockburger](#)
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[Send email to the author](#)
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TABLE OF CONTENTS

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[TESTING A SINGLE CORRELATION](#)
[NORMAL CURVE AREAS](#)
[CRITICAL VALUES FOR THE t-DISTRIBUTION](#)
[CRITICAL VALUES FOR THE CHI-SQUARE DISTRIBUTION](#)
[CRITICAL VALUES FOR](#)




INTRODUCTORY STATISTICS: CONCEPTS, MODELS, AND APPLICATIONS

WWW Version 1.0
 First Published 7/15/96
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 Revised 2/19/98

David W. Stockburger
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 Deputy Director of Academic Assessment, US Air Force Academy

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Award Winning Text

Find the second edition of the text at [Atomic Dog Publishing](#) [math.com](#) [www.rockhillpress.com](#)

Watch for a "learning-focused" third edition of the text starting Spring, 2007 published by Atomic Dog Publishing.

Figure 4: A Screenshot of Stockburger's Website Main Page

The major features of the text include development of the concept of creating mathematical models of the world, a slightly different organizational scheme than most introductory texts, with material presented in the following order: frequency polygons, and models of frequency polygons, the normal curve, and then statistics. In addition, the presentation of transformations, linear transformations, and then linear regression follows a natural progression of material. Page layout is made consistent throughout the website such that table of contents are always on the left side of each page and its corresponding explanation is always on the right side of the page. Each concept is accompanied with an example to explain the concept more precisely. Figure 5 is the screenshot of the statistical concept 'Sampling distribution' that is explained using a graphic display.

THE SAMPLING DISTRIBUTION

DEFINITION

The sampling distribution is a distribution of a sample statistic. While the concept of a distribution of a set of numbers is intuitive for most students, the concept of a distribution of a set of statistics is not. Therefore distributions will be reviewed before the sampling distribution is discussed.

THE SAMPLE DISTRIBUTION

The sample distribution is the distribution resulting from the collection of actual data. A major characteristic of a sample is that it contains a finite (countable) number of scores, the number of scores represented by the letter N . For example, suppose that the following data were collected:

32 35 42 33 36 38 37 33 38 36 35 34 37 40 38 36 35 31 37 36 33
36 39 40 33 30 35 37 39 32 39 37 35 36 39 33 31 40 37 34 34 37

These numbers constitute a sample distribution. Using the procedures discussed in the chapter on frequency distributions, the following relative frequency polygon can be constructed to picture this data:

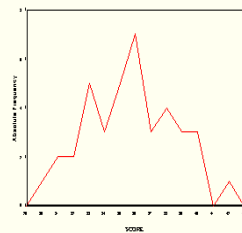


Figure 5: A Screenshot of a Statistics Concept ‘Sampling Distribution’ from Stockburger’s Website

Some potential benefits of the electronic teaching materials such as web-based tutorials are, (1) students can have access to web pages any time - yet they can have instructors guidance, (2) students can be independent learners and take as much time as he/she wants to review the topics, (3) students can interact well in the class if they have studied the topic online and the physical time in the classroom is reduced, (4) yet there is still face to face contact between students and faculty.

Coppola’s Tutorial on Central Limit Theorem

Coppola (2000) developed a tutorial to explain the concepts of the central limit theorem; it is similar to traditional instruction methods in that the material used is theoretical and did not include animations. The phenomenon of the central limit theorem

is explained with an example. Properties of the central limit theorem through sampling of the normal distribution are discussed. By relating the Z transformation to the central limit theorem a formula for Z is derived.

Godden's Tutorial on Confidence Interval

Godden (2004) developed a tutorial for confidence intervals. The definition of the confidence interval is explained through an example. The factors that affect a confidence interval for a given confidence level such as sample size, percentage, and population size are discussed in detail. Static displays are not included in this tutorial.

SEMATECH'S Tutorial on Tolerance Interval

NIST/SEMATECH (2002) is an e-Handbook of Statistical Methods to help engineers and scientists while incorporating statistical methodologies in their work. The tolerance interval concept is explained in this handbook in a text-based environment. The difference between confidence and tolerance intervals are discussed, following by properties of tolerance intervals for a normal distribution.

Wachsmuth's Tutorial on Linear Regression

Wachsmuth (1998) designed a website mathcs.org to teach introductory statistics concepts with static images and audio. The website has been updated periodically since 1998 until 2009. Linear Regression is explained using an example data from two variables that are possibly related. But the exact nature of the relationship between two

variables is determined and a few formulas can be used to make predictions about the dataset.

2.3.3.2 Web Lessons with Graphics and Animations

Web lessons with graphics and animations are another type of statistical instruction method. In this, visualization is used to teach statistical topics in a web-based course. A review of web-based statistical lessons such as WISE (Web Interface for Statistics Education), MM Stat, Rice Virtual Lab and Statistica are discussed. A brief overview of web-based lessons that includes five topics such as Coleman's tutorial on normal distribution, Berger's tutorial on central limit theorem, Lane's tutorial on confidence interval and lastly West and Ogden's tutorial on linear regression are discussed. These five statistics topics are selected by SME's (Subject Matter Expert's) for this project implementation.

WISE (Web Interface for Statistics Education)

Mike, Victoria, Chris and Dale (2009) developed an interactive web-based tutorial called a web interface for statistics education (WISE). A special feature of WISE is the sequence of interactive tutorials on some key statistical concepts including sampling distributions, the central limit theorem, hypothesis testing, and statistical power. Figure 6 shows the welcome page of WISE and the layout of links to statistical concepts that are taught in the interface.

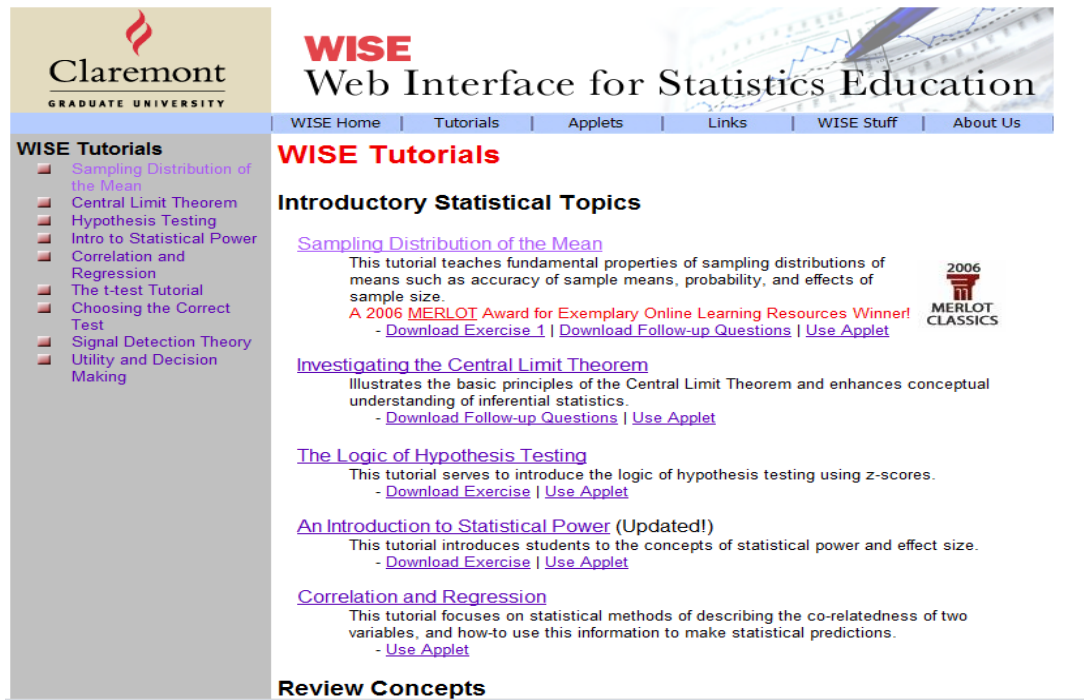


Figure 6: A Screenshot of the Index Page for Introductory Statistical Concepts from WISE

WISE uses dynamic applets that allow users to explore relationships at their own pace. Guided exercises are designed to help the learner take full advantage of the applets in gaining a deeper understanding of the concepts and logic that underlie much of inferential statistics. Each tutorial includes a java applet, questions at the end of each topic and review materials.

MM Stat

MM Stat (Ronz, Muller & Ziegenhagen, 2000) was an interactive browser-based tool for teaching statistics. MM*STAT was designed as a teaching and learning tool for an introductory statistics course. It contains the common and well-known topics and some basic statistics concepts such as one-dimensional frequency distributions, basics of

probability calculus, random variables, probability distributions, sampling theory, estimation methods, hypothesis testing, two-dimensional frequency distributions, regression analysis, and time series analysis. MM Stat is aimed at supplementing the traditional lectures by creating a framework to repeat and practice the content of lectures. Students are challenged by providing a question and answer session.

Rice Virtual Lab

Rice virtual lab is a web-based Online Statistics tutorial which acts as an Interactive Multimedia Course of Study to an introductory-level statistics book (<http://onlinestatbook.com/index.html>). The material is presented both as a standard textbook and as a multimedia presentation. The textbook features interactive demonstrations and simulations, case studies, and an analysis lab (Lane, Lu, Peres & Zitek. 2008). It covers topics such as graphing distributions, describing bivariate data, probability, normal distribution, hypothesis testing, power, regression, analysis of variance and many other important statistical concepts. The Rice Virtual Lab material can be viewed in three presentation modes: **standard**, **condensed**, and **multimedia**. The standard mode includes real-world examples, self-testing questions, and interactive simulations and demonstrations. Figure 7 is the screenshot of the Rice virtual lab in standard mode. A user is allowed to choose the topic of interest by selecting contents and chapter section, as illustrated in Figure 7.

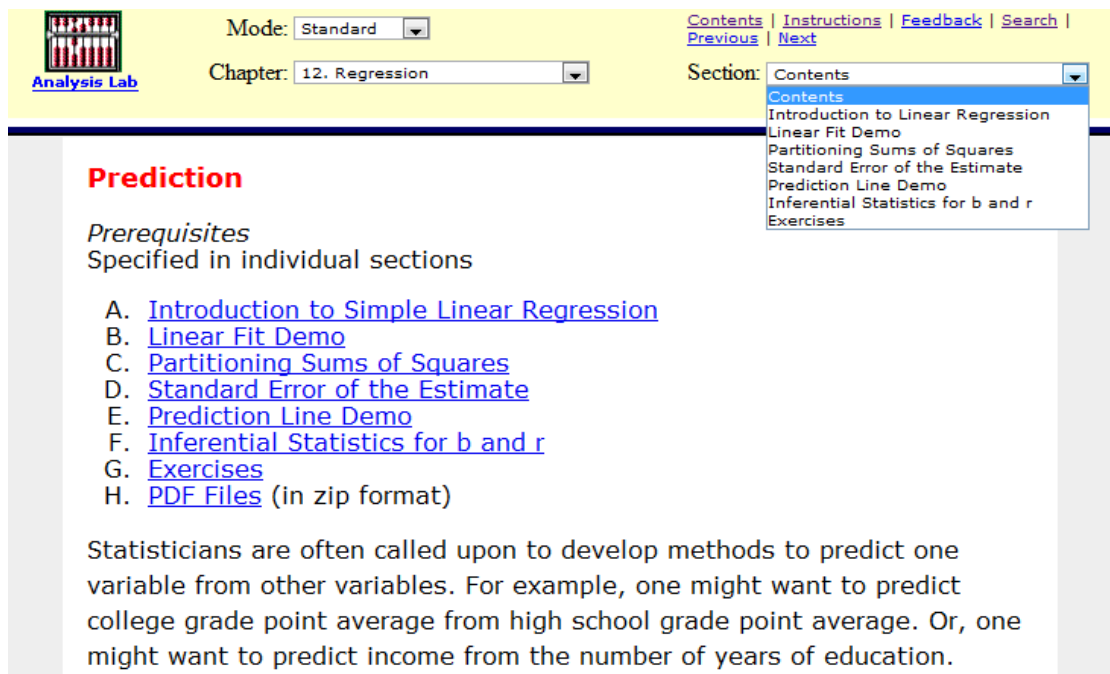


Figure 7: A Screenshot of Rice Virtual Lab Webpage in Standard Mode with Chapter and Content Selection List

The condensed mode contains just the critical information with a few examples and not much text. The multimedia mode presents a lecture with audio presented over a slide presentation. The multimedia presentations require QuickTime. Figure 8 is the screenshot of the tutorial in multimedia mode.

Finally, the simulations and self-test programs require Java. The user chooses the mode by the drop-down menu labeled 'mode' located at the upper left hand portion of the browser window, as illustrated in Figures 7 and 8. The glossary page is also included in the website which contains all the definitions of terms used during the lecture. The user has access to the glossary page any time from the index page. Figure 9 is a screenshot of the glossary page of Rice virtual lab where the table of contents is placed on the left side and the explanation is placed on the right side.

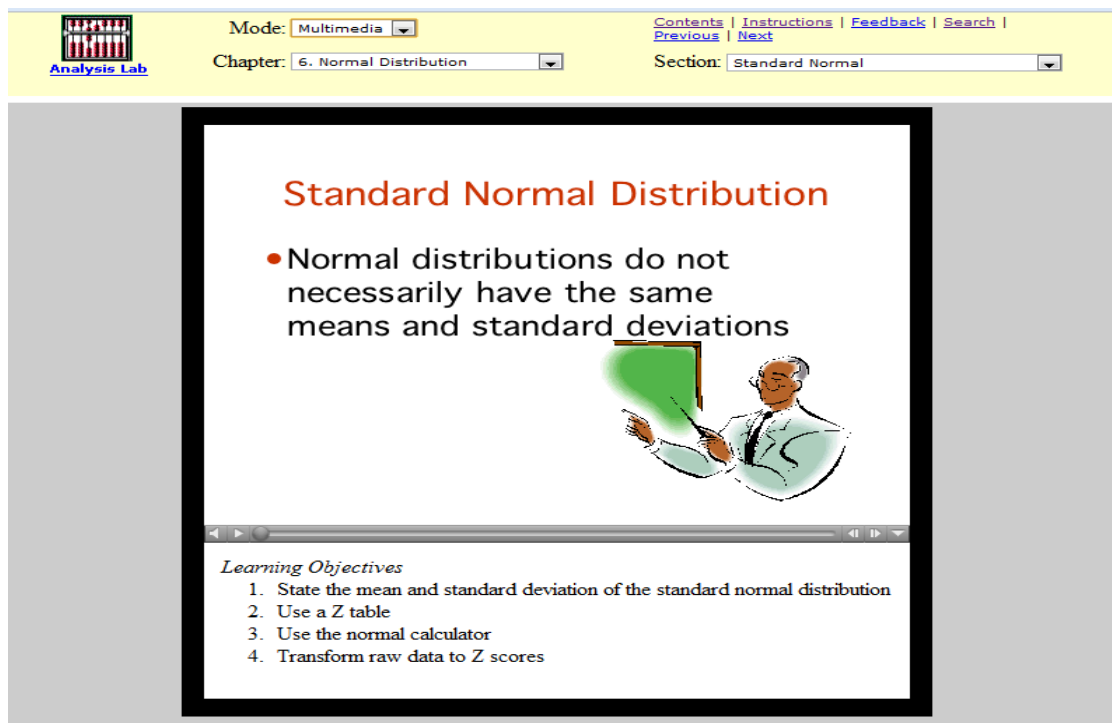


Figure 8: A Screenshot of ‘Standard Normal Distribution’ Tutorial in Multimedia Mode from Rice Virtual Lab

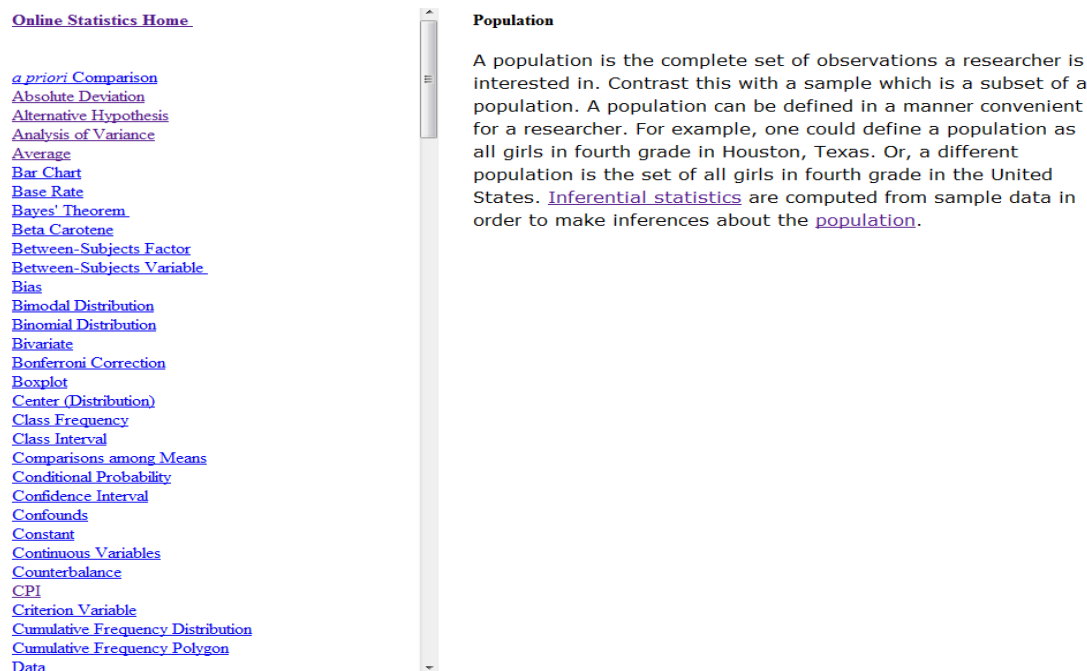


Figure 9: A Screenshot of Glossary Page of Rice Virtual Lab

Statistica

Statsoft Inc produces an Electronic Statistics Textbook called Statistica (2008) which is a high performance statistical performance analysis and graphics software (<http://www.statsoft.com/textbook/stathome.html>). This Electronic Statistics Textbook offers training in the understanding and application of statistics. The material was developed at the StatSoft R&D department based on many years of teaching undergraduate and graduate statistics courses and covers a wide variety of applications, including laboratory research (biomedical, agricultural, etc.), business statistics and forecasting, social science statistics and survey research, data mining, engineering and quality control applications, and many others (Hill & Lewicki, 2007). Figure 10 is the screenshot of the Statistica's mainpage.



The screenshot displays the Statistica website's main page. At the top center is the StatSoft logo, featuring a stylized 'S' and the text 'ELECTRONIC TEXTBOOK StatSoft'. Below the logo is a search bar with the placeholder text 'To search the Electronic Statistics Textbook for terms and general statistical concepts, enter keywords/phrases below:'. To the right of the search bar are 'Search' and 'Clear' buttons, and a link to 'Search Tips'. On the left side, there is a promotional banner for a printed version of the textbook, 'STATISTICS: Methods and Applications', priced at \$80, which includes a coupon for a free CD version. The banner also mentions that the book is available on Amazon.com. To the right of the banner is a Britannica Internet Guide Award logo, with text stating 'The only Internet Resource about Statistics Recommended by Encyclopedia Britannica'. On the right side of the page is a vertical 'CONTENTS' menu with a list of topics: Elementary Concepts, Basic Statistics, ANOVA/MANOVA, Association Rules, Boosting Trees, Canonical Analysis, CHAD Analysis, C & R Trees, Classification Trees, Cluster Analysis, Correspondence Analysis, Data Mining Techniques, Discriminant Analysis, Distribution Fitting, Experimental Design, Factor Analysis, General Discrim. Analysis, General Linear Models, Generalized Additive Mod., Generalized Linear Mod., General Regression Mod., Graphical Techniques, Ind. Components Analysis, Linear Regression, Log-linear Analysis, and MARSplines. The main content area below the search bar contains a paragraph about the textbook's purpose and a section titled 'Elementary Concepts in Statistics' with an 'Overview of Elementary Concepts in Statistics' section.

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The only Internet Resource about Statistics Recommended by Encyclopedia Britannica

This Electronic Statistics Textbook offers training in the understanding and application of statistics. The material was developed at the StatSoft R&D department based on many years of teaching undergraduate and graduate statistics courses and covers a wide variety of applications, including laboratory research (biomedical, agricultural, etc.), business statistics and forecasting, social science statistics and survey research, data mining, engineering and quality control applications, and many others.

The Electronic Textbook begins with an overview of the relevant elementary (pivotal) concepts and continues with a more in depth exploration of specific areas of statistics, organized by "modules," accessible by buttons, representing classes of analytic techniques. A glossary of statistical terms and a list of references for further study are included.

Proper citation: (Electronic Version): StatSoft, Inc. (2007). Electronic Statistics Textbook. Tulsa, OK: StatSoft. WEB: <http://www.statsoft.com/textbook/stathome.html>
Proper citation: (Printed Version): Hill, T. & Lewicki, P. (2007). STATISTICS Methods and Applications. StatSoft, Tulsa, OK.

Elementary Concepts in Statistics

Overview of Elementary Concepts in Statistics. In this introduction, we will briefly discuss those elementary statistical concepts that provide the necessary foundations for more specialized expertise in any area of statistical data analysis. The selected topics illustrate the basic assumptions of most statistical methods and/or have been demonstrated in research to be necessary components of one's general understanding of the "quantitative nature" of reality (Nisbett, et al., 1987). Because of space limitations, we will focus mostly on the functional aspects of the concepts discussed and the presentation will be very short. Further information on each of those concepts can

Figure 10: A Screenshot of Statistica Website Main Page

The Electronic Textbook begins with an overview of the relevant elementary concepts and continues with a more in depth exploration of specific areas of statistics, organized by "modules," accessible by buttons, representing classes of analytic techniques. In an overview of Elementary Concepts in Statistics, Statistica focuses on a brief discussion of those elementary statistical concepts that provide necessary foundations for more specialized expertise in any area of statistical data analysis. The selected topics illustrate the basic assumptions of most statistical methods and/or have been demonstrated in research to be necessary components of one's general understanding of the "quantitative nature" of reality (Nisbett, 1987). Statistics includes basic statistical concepts and a glossary page, as shown in Figure 11 which is accessed by the user any time.

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Elementary Concepts in Statistics

Overview of Elementary Concepts in Statistics. In this introduction, we will briefly discuss those elementary statistical concepts that provide the necessary foundations for more specialized expertise in any area of statistical data analysis. The selected topics illustrate the basic assumptions of most statistical methods and/or have been demonstrated in research to be necessary components of one's general understanding of the "quantitative nature" of reality (Nisbett, et al., 1987). Because of space limitations, we will focus mostly on the functional aspects of the concepts discussed and the presentation will be very short. Further information on each of those concepts can be found in statistical textbooks. Recommended introductory textbooks are: Kachigan (1986), and Runyon and Haber (1976); for a more advanced discussion of elementary theory and assumptions of statistics, see the classic books by Hays (1988), and Kendall and Stuart (1979).

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- [Dependent vs. independent variables](#)
- [Measurement scales](#)
- [Relations between variables](#)
- [Why relations between variables are important](#)
- [Two basic features of every relation between variables](#)
- [What is "statistical significance" \(p-value\)](#)
- [How to determine that a result is "really" significant](#)
- [Statistical significance and the number of analyses performed](#)
- [Strength vs. reliability of a relation between variables](#)
- [Why stronger relations between variables are more significant](#)

- [Why significance of a relation between variables depends on the size of the sample](#)
- [Example: "Baby boys to baby girls ratio"](#)
- [Why small relations can be proven significant only in large samples](#)
- [Can "no relation" be a significant result?](#)
- [How to measure the magnitude \(strength\) of relations between variables](#)
- [Common "general format" of most statistical tests](#)
- [How the "level of statistical significance" is calculated](#)
- [Why the "Normal distribution" is important](#)
- [Illustration of how the normal distribution is used in statistical reasoning \(induction\)](#)
- [Are all test statistics normally distributed?](#)
- [How do we know the consequences of violating the normality assumption?](#)

What are variables. Variables are things that we measure, control, or manipulate in research. They differ in many respects, most notably in the role they are given in our research and in the type of measures that can be applied to them. [To index](#)

Correlational vs. experimental research. Most empirical research belongs clearly to one of those two general categories. In correlational research we do not (or at least try not to) influence any variables but only measure them and look for relations (correlations) between some set of variables, such as blood pressure and cholesterol level. In experimental research, we manipulate some variables and then measure the effects of this manipulation on other variables; for example, a researcher might artificially increase blood pressure and then record cholesterol level. Data analysis in experimental research also comes down to calculating "correlations" between variables, specifically, those manipulated and those affected by the manipulation. However, experimental data may potentially provide qualitatively better information. Only experimental

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GLOSSARY
StatSoft

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Figure 11: A Screenshot of Elementary Statistical Concepts Page from Statistica Website

Figure 12 is the screenshot of an animation that was presented to explain Linear Regression. Animation was used to show a regression equation plotted with three different confidence intervals. In Statistica, mostly the functional aspects of the concepts are discussed and the presentation is short due to space limitations. A glossary of statistical terms and a list of references for further study are included. In the glossary page of Statistica, a user can click on the first letter of his/her topic of interest and the content related to the selected statistical topic is displayed on the screen, as illustrated in Figure 13.

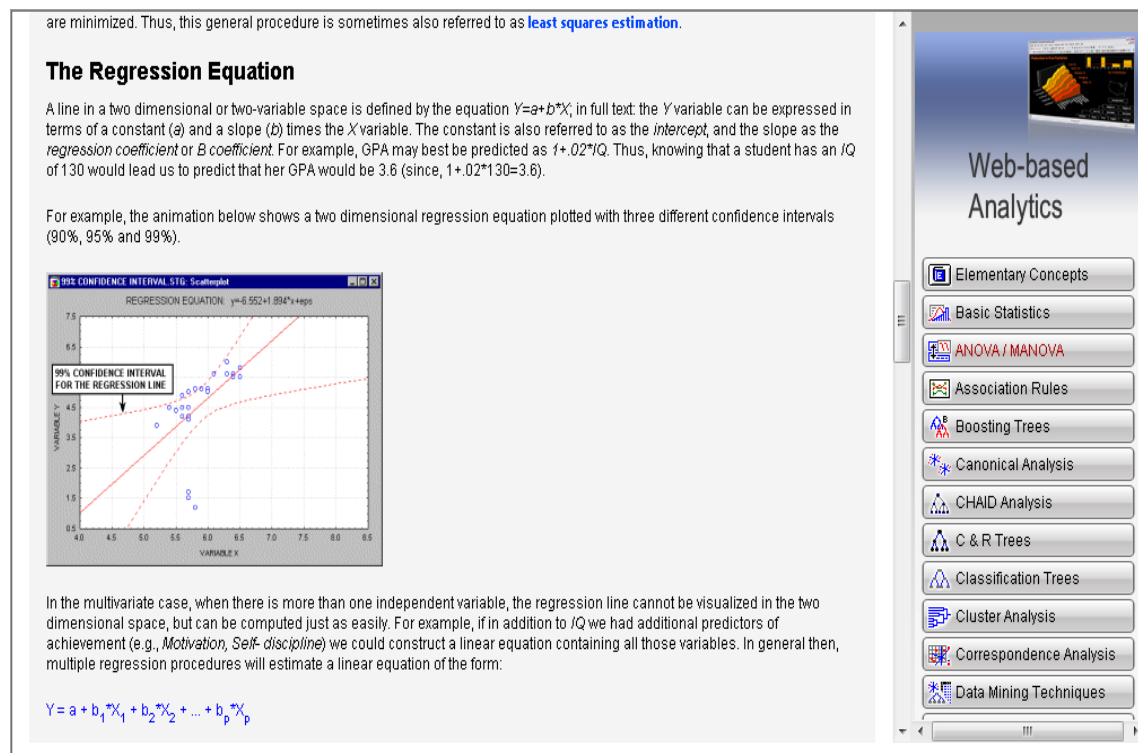


Figure 12: A Screenshot of Animated Regression Line to Explain Regression Equation from Statistica Website

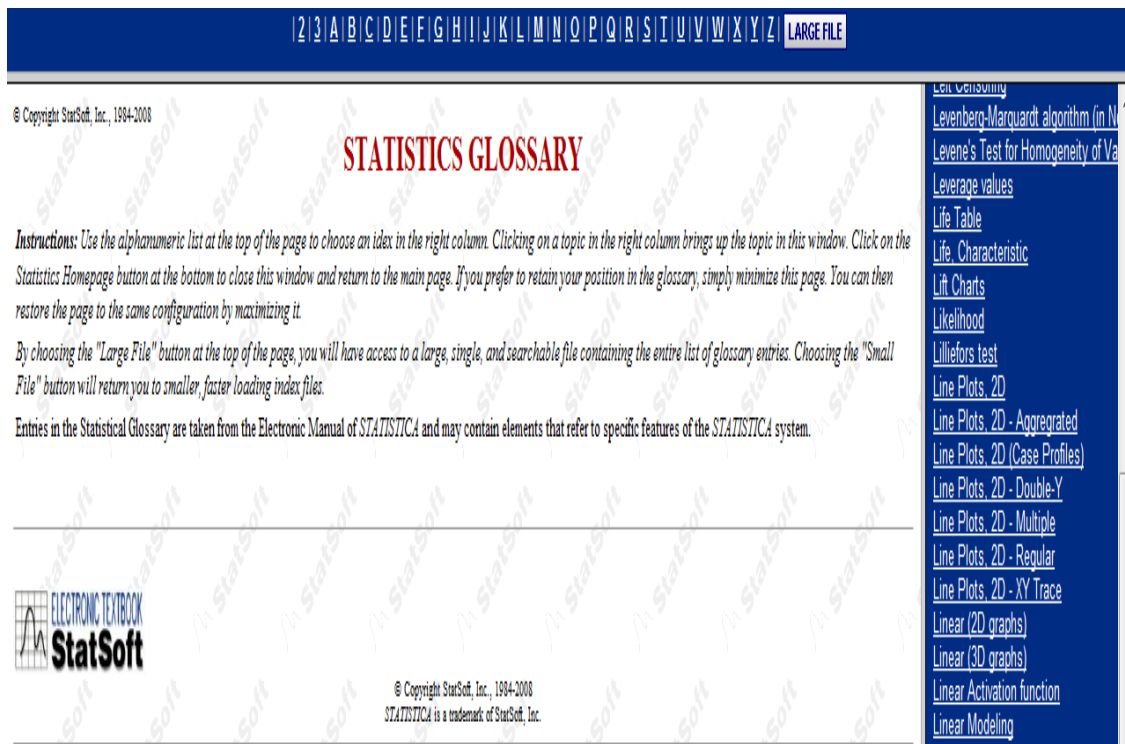


Figure 13: A Screenshot of Statistics Glossary Page from Statistica Website

Coleman's Tutorial on the Normal Distribution

Coleman (1997) developed an interactive tutorial to explain the concepts underlying the normal distribution. This tutorial starts with the definition of the normal distribution along with the representation of a normal curve. An interactive demonstration of the relationship between the standard deviation and the width of the distribution is developed. The animation is designed to interactively demonstrate the fraction of data that lie within a certain range about the mean for normally distributed data. A spreadsheet is set up to calculate a Gaussian distribution when provided with a mean and standard deviation. The spreadsheet further introduces the idea of the histogram and shows how histograms are constructed in Excel.

Berger's Tutorial on Central Limit Theorem

Berger (2005) designed a Central Limit Theorem (CLT) tutorial which uses an applet with exercises to demonstrate CLT concepts visually and interactively. The goals of this tutorial are to illustrate interactively the basic principles of the CLT and to demonstrate when it is possible to assume that the sampling distribution of the mean is reasonably normal. The assumption of normality of the sampling distribution underlies many inferential statistical applications and tests of statistical significance.

Lane's Tutorial on Confidence Interval

Lane (2006) developed Java applets that demonstrate various statistical concepts. Confidence Interval is one of them. This applet simulates sampling from a population with a mean of 50 and a standard deviation of 10. For each sample, the 95% and 99% confidence intervals for the mean are computed based on the sample mean and sample standard deviation. In confidence interval simulation, the intervals for various samples are displayed by horizontal lines, as shown in Figure 14. The simulation demonstrates the variation in the sample mean, from sample to sample, and illustrates how confidence interval width depends on the sample size and the confidence level.

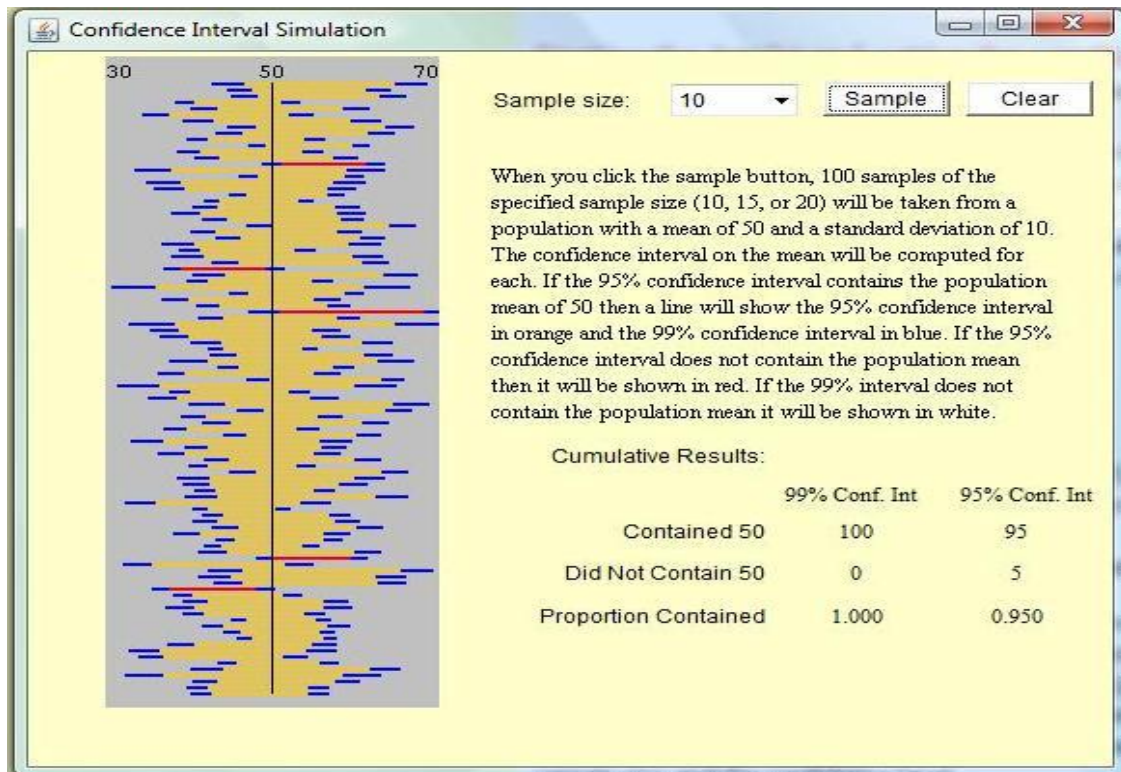


Figure 14: A Screenshot of the Confidence Interval Simulation

West and Ogden's Tutorial on Linear Regression

West and Ogden (1998) created a visual method to help students understand how individual points can affect a regression line and which outliers cause the maximum effect. In this data-driven animation, students are able to move data points to different locations on the scatter plot. Each time a data point is moved, the computer redraws the regression line. Thus, students will be able to comprehend the principle that the regression line comes as close as possible to each point in the data set.

2.3.4 Virtual Environment Used for Statistics Instruction

Utah Virtual Lab

Malloy and Jensen (2001) designed a Java-based online virtual lab called Utah Virtual Lab which is embedded in StatCenter, an online collection of tools and text for teaching and learning statistics. Utah Virtual Lab is a statistical virtual space that simulates theories and data in a specific research focus area by defining independent, predictor, and dependent variables and the relations among them. Students work in an online virtual environment to discover the principles of this simulated reality. In this lab students go to a library, read theoretical overviews and scientific puzzles, and then go to a lab, design a study, collect and analyze data, and finally write a report. Its authoring tool allows an instructor to create text-based research projects appropriate to any research area where statistical tools such as the mean, variance, t-distribution, F- distribution, Chi-square-distribution, and regression are appropriate.

A student's design and data analysis results are graded by the computer and recorded in a database. In addition, the written research report is read by the instructor or other students in peer groups simulating scientific conventions. The Utah Virtual Lab is used to support any empirically based course in social sciences where students will benefit from discovering for themselves an accepted knowledge base in addition to learning about it in traditional ways.

Utah Virtual Lab allows instructors to generate simulated realities based on statistical equations. These equations generate data uniquely for each student. Instructors can simulate principles and accepted research findings that they want students to

experience. Like real researchers, no two students will get exactly the same results even when they do the same study. The virtual lab engages students in scientific discovery processes by giving them the compressed experience of making many systematic research strategy decisions with the goal of discovering the principles of a complex virtual reality. The data simulations of the Utah Virtual Lab are non-comprehensive and less sophisticated, but they are well tailored to an introductory statistics course and are available online.

The navigation pages encountered by users in the Utah Virtual Lab to learn statistical concepts and understand their applications are illustrated in Figures 15-21. The user has to click on the ‘now open’ button or place the mouse on the door to enter the lab, as shown in Figure 15. After entering the lab, users can move the mouse around the library to see different course titles and instructors. In this page the user has to click on the course, as illustrated in Figure 16.



Figure 15: A Screenshot of Welcome Screen of Utah Lab

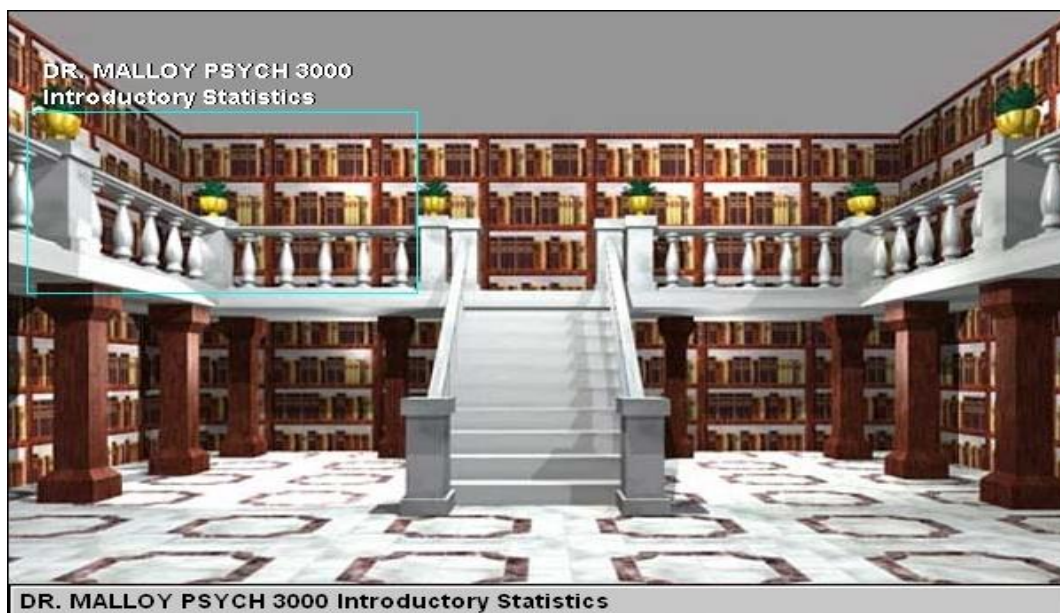


Figure 16: A Screenshot of Webpage for Selecting a Statistical Concept from the Virtual Library

The statistical concept that is selected from the library or the user interface that is provided to select a statistical concept as shown in figure 16, navigates the user to a page that displays some topics concerning that statistical concept, as illustrated in Figure 17. In this page, books will appear. The user has to click on one of them. Its full title appears below the graphic, the user has to click ‘next’ to start reading the book. In the following page a brief overview of the selected statistical topic is given, as shown in Figure 18. Following the overview, the user enters a page where he/she has to select a chapter to practically apply what is learned in the overview. The full title of the selected chapter will appear in the large aqua-colored bar below the chapter icons, as shown in Figure 19. Each chapter will present a story problem (scientific puzzle) to the user that must be solved by doing research. The chapter that is selected takes user to a page that contains four different labs for doing different kinds of research. At this time virtual labs are introduced

into the course, as illustrated in Figure 20. A lab selected by the user is shown in Figure 21. In this example, the user selected Experimental Research One IV. This lab allows the user to investigate the effect of one IV on a Dependant Variable.

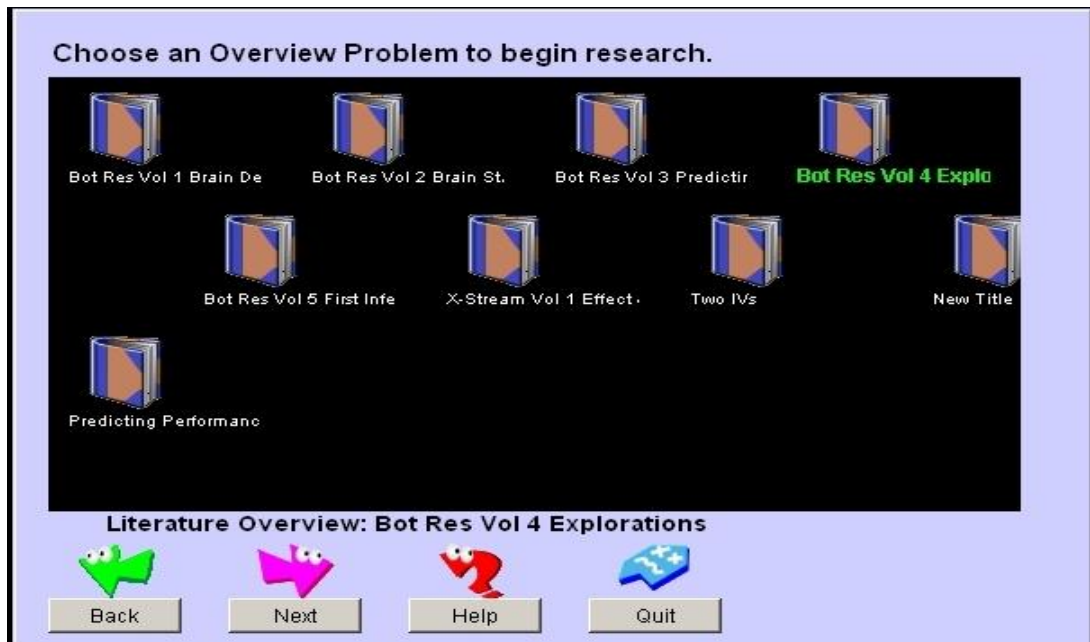


Figure 17: A Screenshot of Statistical Topic Contents Page from Utah Lab

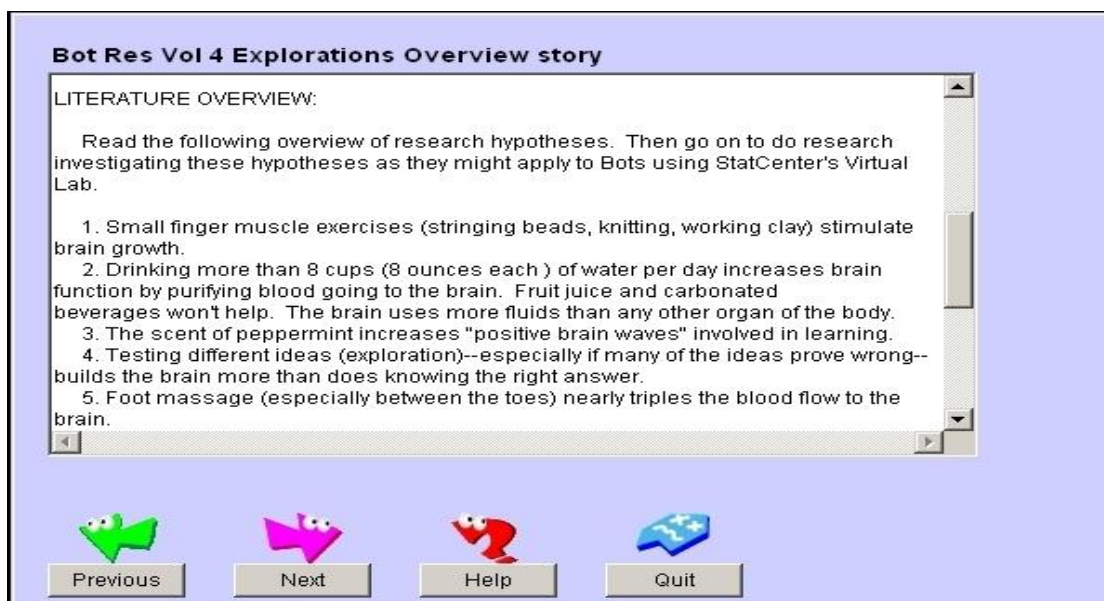


Figure 18: A Screenshot of the Page that gives an Overview of the Selected Statistical Concept



Figure 19: A Screenshot of the Page where User has to Select a Chapter for Research

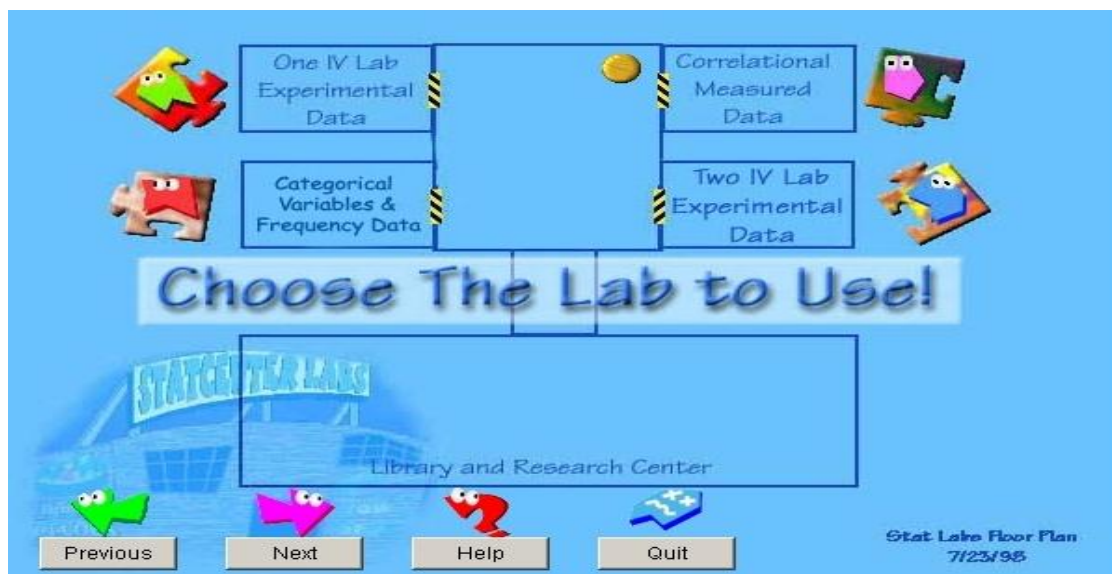


Figure 20: A Screenshot of the Page with Four Different Virtual Labs



Figure 21: A Screenshot of the Page for Application of a Statistical Concept from Utah Virtual Lab

“New Statistics”– A Virtual Learning Environment

Mittag (2004) developed ‘New Statistics’, a virtual learning environment for statistics education. This project contained more than 70 learning modules covering the complete curriculum of an introductory statistics course. All modules were based on an innovative learning laboratory called the statistical lab, the programming language for performing ad-hoc analyses of user-defined data sets, Java applets for trying out statistical concepts by means of user controlled experiments, flash animations to explain statistical theory and case studies related to different sciences and applications. These interactive applets were used as supplements to traditional lecturing or for self study purposes.

A brief overview of the discussed web-based lessons is provided in the following table 1. In the content column of the table only those statistical concepts that are related to the purpose of this project are mentioned even though the statistical course provides training on various other statistical concepts.

Table 1: Summary of web-based lessons of statistical concepts

Courses	References	Content	Representation
Hyperstat	http://davidmlane.com/hyperstat/index.html	Introduction to Statistics Normal Distribution, Sampling Distribution, Confidence Intervals, Hypothesis Testing Power, Anova, etc..	Text-based
Stockburger's web-based statistical course	http://www.psychstat.missouri-state.edu/introbook/sbk00.htm	The Normal Curve, Statistics, Regression Models, Correlations, Hypothesis Testing, The Sampling Distribution, Correlation coefficients, Scatter plot, Bibliography and Web Resources, etc...	Text-based
Coppola's tutorial on Central Limit Theorem	Coppola (2000)	Central Limit Theorem	Text-based
Godden's tutorial on Confidence Interval	Godden (2004)	Confidence Interval	Text-based

Table 1 (Continued)

SEMATECH's tutorial on Tolerance Interval	NIST/SEMATECH (2002)	Tolerance Interval	Text-based
Wachsmuth's tutorial on Linear Regression	Wachsmuth (1998)	Linear Regression	Text-based
WISE (Web Interface for Statistics Education)	Mike, Victoria, Chris and Dale (2009)	Sampling Distribution of the mean, Central Limit Theorem, Hypothesis Testing, Correlation and Regression, etc.. Applets for Sampling Distribution of the mean, Hypothesis Testing, etc..	Lessons with graphics and animations
MM Stat	Ronz, Muller & Ziegenhagen (2000)	Sampling Distribution, Hypothesis Testing, Regression Analysis, etc...	Lessons with graphics and animations
Rice Virtual Lab	http://onlinestatbook.com/index.html	Introduction to Statistics, Normal Distribution, Sampling Distribution, Logic of Hypothesis Testing, Glossary, etc...	Lessons with graphics and animations

Table 1 (Continued)

Berger's tutorial on Central Limit Theorem	Berger (2005)	Central Limit Theorem	Lessons with graphics and animations
Lane's tutorial on Confidence Interval	Lane(2006)	Confidence Interval	Lessons with graphics and animations
West and Ogden's tutorial on Linear Regression	West and Ogden (1998)	Linear Regression	Lessons with graphics and animations
Utah Virtual Lab	www.psych.utah.edu	Hypothesis Testing, Linear Regression, etc...	Virtual environment based statistics instruction
New Statistics	Mittag (2004)	Introductory Statistics Courses	Virtual environment based statistics instruction

2.4 Instructional Design and Development Process

The design and development process that this project followed is the well-known “Systems Approach Model for Designing Instruction” introduced by Dick and Carey in their book “The Systematic Design of Instruction” published in 2005. The eight stages of designing instruction are, (1) identifying instructional goals, (2) conducting instructional analyses, (3) analyzing learners and context (determining entry behaviors), (4) writing performance objectives, (5) developing assessment instruments (deciding on instructional strategies), (6) developing instructional strategy (creating instructional materials), (7) develop and select instructional materials (conducting formative evaluations), and (8) designing and conducting a summative evaluation (conducting a summative evaluation).

In next eight paragraphs, each stage is explained briefly based on ‘The Systematic Design of Instruction’ by Dick and Carey (2005). After each stage is explained, their application to this project (Web-Based Teaching of Statistical concepts with Graphics and Animations) is discussed.

The main goal of this project is to a design a website that teaches statistical concepts through graphics and animations. This goal is pre-established through background literature review on statistics instruction. Following the goal, an initial need analysis is conducted through discussions with faculty members who have taught statistical courses in the Department of Biomedical, Industrial, and Human Factors Engineering at Wright State University. Through this analysis, statistical concepts that are important yet difficult to understand and whose presentation would be enhanced with the use of graphics and animations are identified.

Based on the analysis, statistical concepts such as the central limit theorem, normal distribution, confidence interval, and linear regression are considered to be appropriate concepts for the thesis. Due to time limits, this project mainly focuses on entry-level statistical concepts.

At the first stage, instructional goals are identified. The instructional goals are derived through performance analysis and need analysis and by understanding the learning difficulties of students. A list of instructional goals and project objectives are determined at this stage.

Next, student's skill levels, knowledge and attitude that are required to start the instruction are determined and the contexts in which students will learn the skills and use them are analyzed (stages 2 and 3). Pre-requisite knowledge that is necessary for students is determined by reviewing introductory statistics text books, instructor's presentation notes of introductory statistics courses, and discussing with SME's. These steps are essential for creating a rough draft of basic concepts that are to be covered while designing the instructional materials. For this project, discussion with the SME's has revealed students' choices of learning and how they are to be taught.

Specific instructional objectives with respect to the statistical concepts that are to be taught are then determined. At this stage it is important to know what learners will be able to grasp or understand when the instruction is complete (stage 4). For this project, general instructional objectives for each topic are established with help of statistics instructors.

The determined objectives are assessed using questions on topics that are taught in this project. For each question, specific learners' outcomes are defined. At this stage instructors must be able to analyze the topics that are important for students to learn. Also, when topics are taught it is useful to determine if students are able to grasp those topics well (stage 5). For this project, the instructional materials are reviewed and modified repetitively by conducting meetings with SME's. A final assessment questionnaire is framed which is solved by students and saved by the designer for future evaluation.

After the instructional objectives are determined, web-based statistical lessons with graphics and animations are designed and developed for five statistical concepts using HTML and Adobe Flash (stage 6). Instruction materials are selected and developed according to students' learning requirements and feedbacks from an experienced statistics instructor (stage 7). An evaluation is conducted to collect data that is used to test the instruction method. The designed model is implemented on undergraduate students (stage eight).

2.5 Principles of Instructional Design

Gagne, Briggs, and Wager in their book "Principles of instructional design" (Gagne, Briggs, & Wager, 1992) suggested nine instructional activities to support student learning. These activities are: (1) gaining attention, (2) informing the learner of the objective, (3) stimulating recall and prerequisite learning, (4) presenting stimulus material, (5) providing learner guidance, (6) eliciting performance, (7) providing

feedback, (8) assessing performance, and (9) enhancing retention and transfer. The process of instructional design for this project has followed some of the activities.

Gagne et al (1992) also suggested many strategies for gaining learners' attention (first activity) by presenting learning materials that are most appealing to learners. For this project students' attention is gained by designing the welcome page in such a way that it had a brief overview of the website and an animated logo which says "web-based teaching of statistical concepts" to grab learner's attention. Design and layout of the website followed the guidelines compiled by Skaalid, 1999 which are explained in more detail in the section 4.2.

The second activity in instructional design is informing the learner about the objective of the material. According to Gagne et al. (1992), learners should understand "what kind of performance will be used as an indication that learning has, in fact, occurred" (p. 191). For this project, at the beginning of each statistical concept, a list of topics that are covered during the tutorial is mentioned.

During instruction it is important to recall the information that is being learned during the learning process (third activity). For this project, a concept of "z transformation" is repeated in normal distribution lesson and central limit theorem lesson so that students can actually recall what is already learnt previously.

Students must be presented with stimulus material (fourth activity) where the lesson content is actually presented to the learner. To appeal to different learner types, a variety of media should be used that includes text, graphics, audio narration, and video. For this project, lesson content included text along with graphics and animations.

Learner guidance should be designed (fifth activity) to suggest a “line of thought” that will lead learners to make appropriate conclusions about the principles and concepts being taught. This type of guidance helps learners to “keep on the track,” and thus contributes to the efficiency of learning (Gagne et al., 1992, p. 192). For this project, examples that support instruction material were given wherever possible.

When students’ performance is elicited, they should be able to provide correct answers to test questions concerning to the topic that is being taught (sixth activity). This activity serves as an opportunity for learners to become “convinced” that they have acquired new knowledge or skills (Gagne et al., 1992, p. 192). For this project, a posttest questionnaire was framed at the end of each statistical concept to test the effectiveness of students’ learning process.

After student performance is tested, feedback about the student performance must be given immediately to check the correctness of their answer. In the case of web-based instruction, feedback should be immediate and should appear on the same screen that elicits the performance (Clark & Mayer, 2003). Students’ performance must be assessed based on the instructional objectives. Care should be taken to ensure that performance assessments are valid and reliable (Gagne et al., 1992, 193). For this project, students’ test scores were given at the end of the test before proceeding to the next statistical concept. The students’ individual scores were recorded for evaluation during the experiment.

The last activity in instructional design is enhancing retention and transfer (Gagne et al., 1992, p. 198). Knowledge retention can be enhanced by practicing data recall, providing a network relationship for newly learned material, and creating stimulus clues (Gagne et al., 1992, p. 198). For this project, the website that was designed is relatively easy to use and has everything properly organized. In case of problems, users can contact the team anytime by clicking on the “contact us” hyperlink link.

III.DESIGN OF WEB-BASED LESSONS

A usable interface should be easy to learn, easy to use, and easy to navigate through. To build usable web-based statistical lessons, this project follows Dick and Carey's instructional design and development process (Dick & Carey, 2005) and some of Gagne's principles of instructional design (Gagne et al., 1992), and some well-recognized interface and web design guidelines, including Smith and Mosier (1986) and Skaalid (1999).

Skaalid (1999) suggested several rules for designing a website: offering informative feedback, designing dialogs to yield closure, using simple design, reducing short-term memory load, applying multimedia and information overload, and incorporating animation and moving images to focus users' attention.

The web-based statistics lessons were developed using Adobe Flash CS3. Flash's animation tools (e.g., motion tweening) and programming language (Action-script 3.0) provide the ideal means for creating the project's animations. Each page of the lesson is a separate Flash movie and exported from the Flash tools in "Shockwave Flash" (SWF) format. These movies contain the entirety of the lesson's content, including graphics, animations, and navigation tools. The SWF files are then embedded in HTML documents and saved to the WSU department server. As a result, the lessons can be accessed easily with a standard web browser.

3.1 Overall Structure of the Designed Web-Based Course of Statistics

The web-based course is divided into five modules, each representing an important statistical concept. They are the normal distribution, the central limit theorem, confidence/tolerance intervals, linear regression, and hypotheses testing. Their contents are decidedly based on the results of the “Instructional Content Review,” interviews with the SME, and predetermined instructional objectives. Linear regression and hypotheses testing are designed but not yet fully implemented due to time constraints. The modules are designed in such a way that students can either proceed through lessons in a prescribed order or review selected modules in any order. However, for those students who have little knowledge of statistics, it is recommended that they take the course in the prescribed order. The website contains a welcome page with an animated agent that provides introductory learner guidance and navigation buttons. The entire website has audio narration, which presents lesson content and provides learner guidance when necessary.

Figure 22 shows the conceptual diagram of the designed web-based lessons of statistics. From the homepage, the user can choose to go to any of the five statistical concepts – the normal distribution, the central limit theorem, tolerance/confidence interval, linear regression, or hypothesis testing. Each statistical concept consists of several pages to explain important aspects of the concept. The lesson of the normal distribution includes four elements which are viewed consecutively, from defining the normal distribution to explaining how z transformation is performed. The central limit theorem lesson includes three elements starting with defining the central limit theorem to explaining how z - transformation for sampling normal distribution is performed. The

lesson of Tolerance/confidence intervals has two separate web-pages, one for tolerance intervals and the second for confidence intervals. In the tolerance interval tutorial two elements are included, a definition of the tolerance interval and the level of significance. The confidence interval tutorial includes three elements: a definition of the confidence interval, confidence levels & confidence limits and lastly estimation of confidence limits for the population mean μ . The concepts of linear regression and hypothesis testing are still under development. A conceptual diagram of the designed web-based lessons for statistics is illustrated in Figure 22.

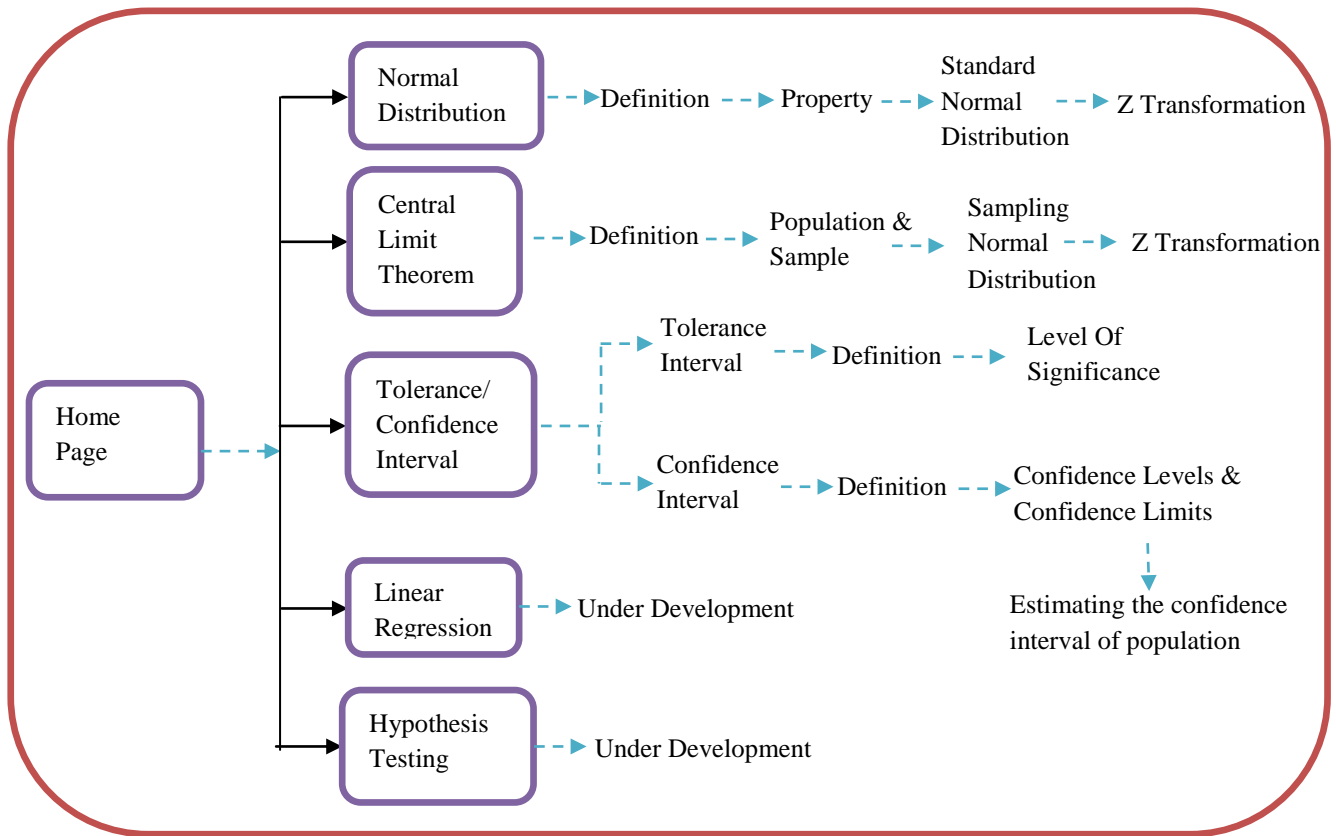


Figure 22: Conceptual Diagram of the Designed Web-Based Lessons of Statistics

3.2 Design Templates

Each of the five statistical concepts is designed as a module. Each concept/module in the design of the web-based course has different contents yet follows a similar basic instructional template based on the nine suggested activities of instruction design described by Gagne et al. (1992). Common pages in each module include a statistical topic definition, module properties with graphics and animations, module summary and conclusion. The contents of each module are divided into manageable pages with text on the left side and graphics and animations on the right side. The navigation buttons at the bottom of each page (illustrated in Figure 23) allow users to move forward and backward through the pages in the same module as they desire. The navigation tool serves a strategic purpose in allowing users to proceed through the lessons at their own pace. While the users are viewing a specific page, they can go to the home page anytime by clicking the home button at the top of the page. The following subsections provide more detailed descriptions of the homepage and the first three modules which have been fully implemented.



Figure 23: A Screenshot of Navigation Buttons of Web-based Statistics Tutorial

3.3 Homepage

After typing in the URL (www.engineering.wright.edu/~webstats) for the web-based course, users are taken directly to its homepage (shown in Figure 24), which provides information on the purpose of the course, sponsor of the project, and link to the

contact information. In addition, links to the five statistical concepts taught in the course are shown on the right side of the screen. These buttons take users to the statistical concepts that are presented using animations and brief explanation of animations through text. These animations, though brief, serve as a means to gain attention and to provide a visual reference to the text (Clark & Mayer, 2003).

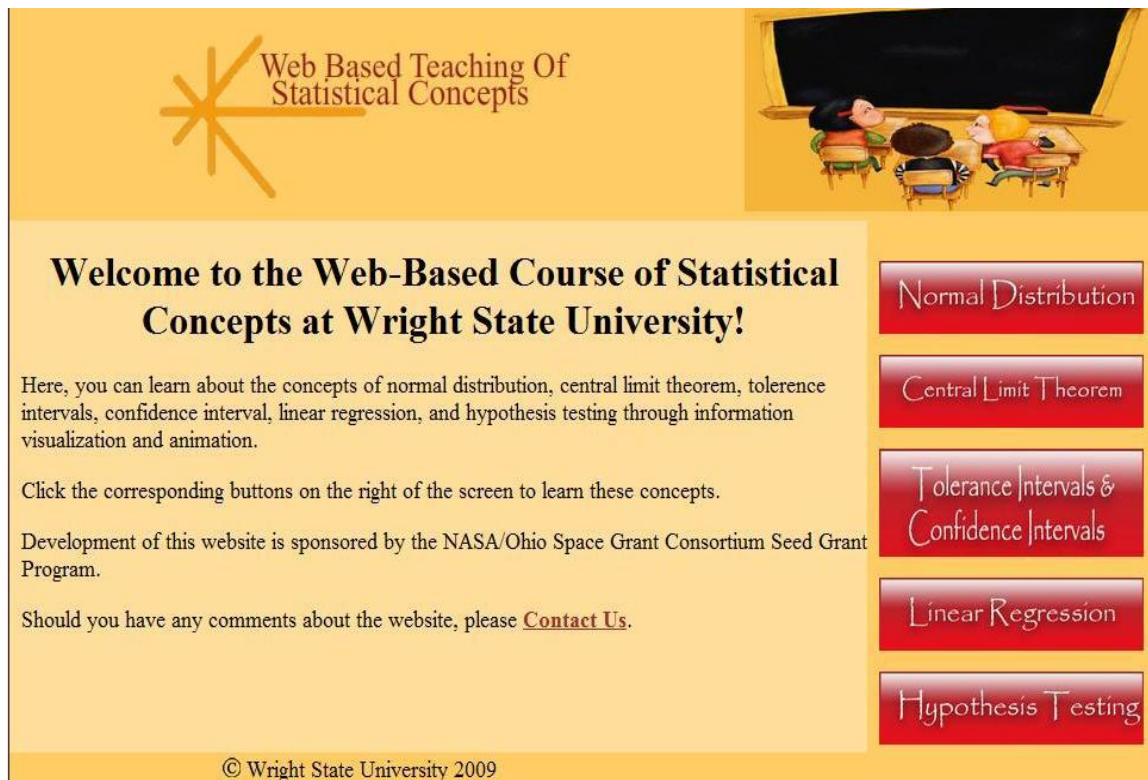


Figure 24: A Screenshot of the Homepage of the Web-Based Course

3.4 Normal Distribution

The first page of this concept gives a definition of normal distribution with a brief explanation. In addition, an animated normally distributed curve is shown in flash player, as illustrated in Figure 25.

In the next three pages of the concept, animations are used to explain the parameters and properties of the normal distribution. Variation in the normally distributed curve for larger and smaller standard deviation is explained through animation, as illustrated in Figure 26. The fifth page defines standard normal distribution, and last few pages explain the procedure for deriving Z transformation.

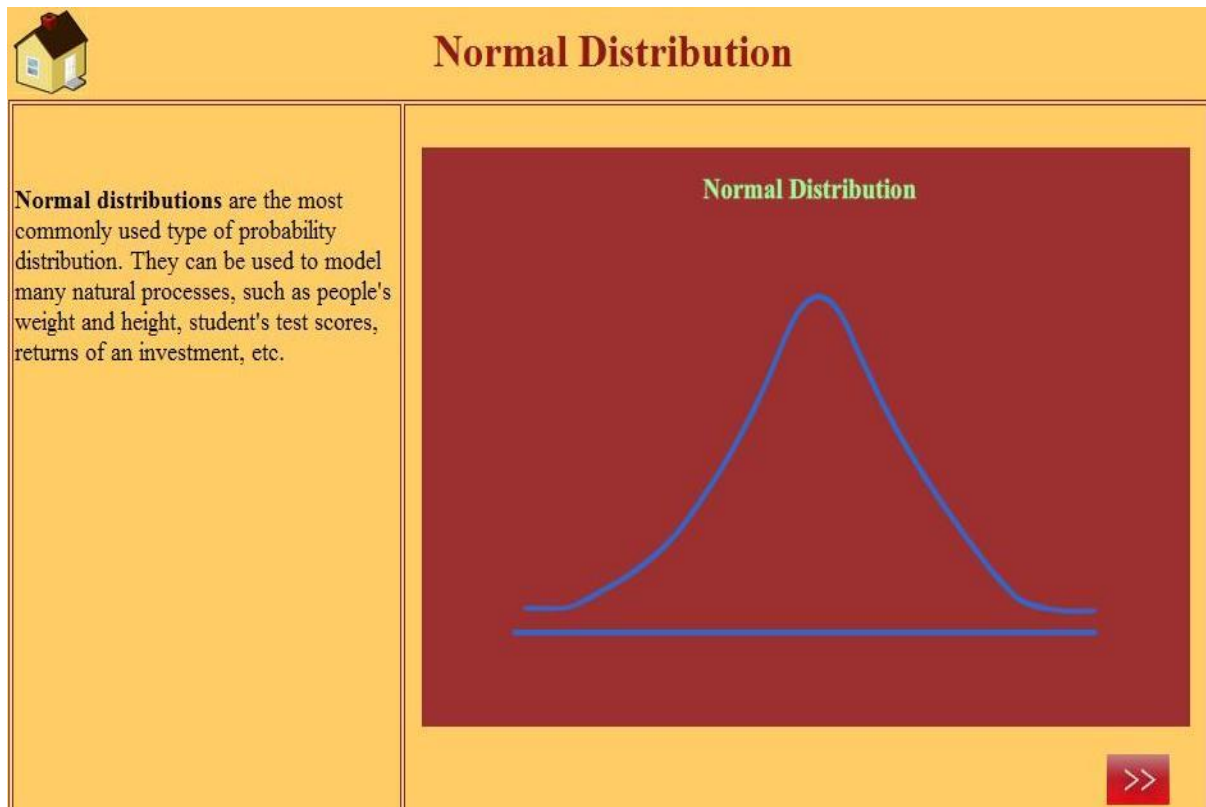


Figure 25: A Screenshot of the Normally Distributed Curve from the Normal Distribution Tutorial

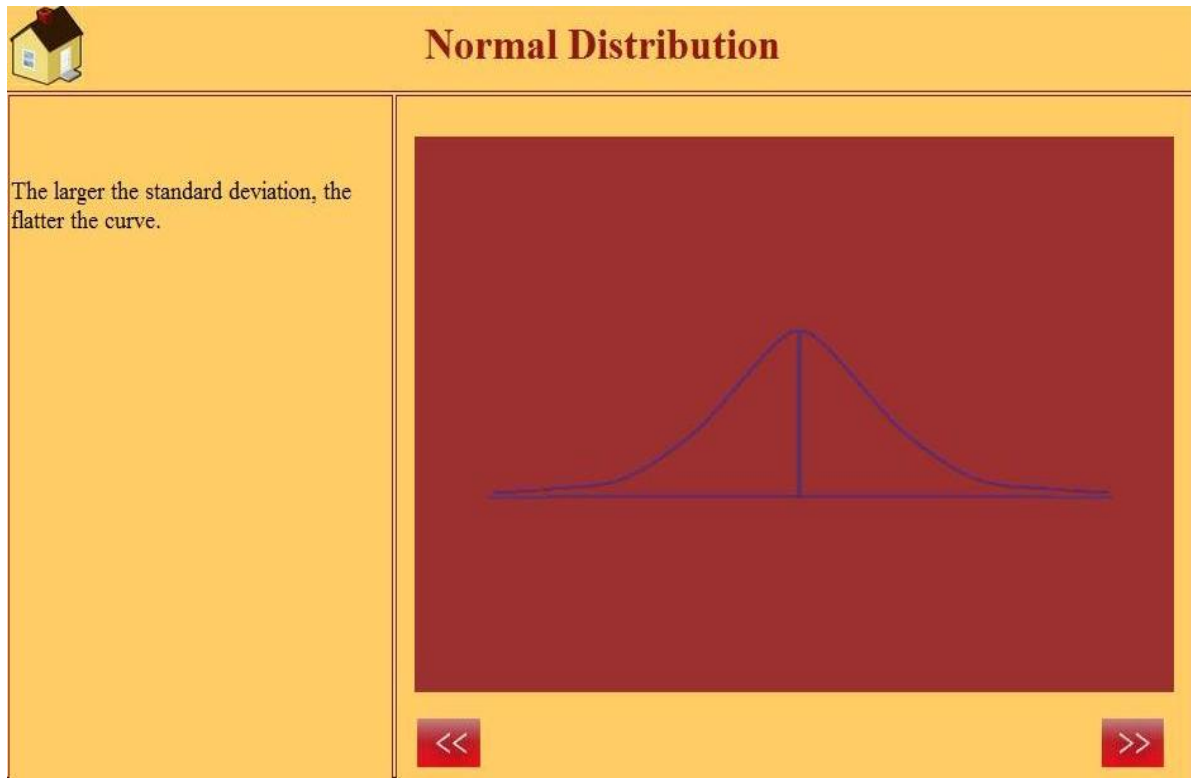



Figure 26 : A Screenshot of the Normally Distributed Curve for Larger Standard Deviation

3.5 Central Limit Theorem

The first page of this concept gives a brief overview of the central limit theorem along with an introduction to terms like mean, variance and standard error, as illustrated in Figure 27. The next page explains the differences between sample and population using both text and animations, as illustrated in Figure 27. In the animations, population and sample are illustrated with people moving from the population block to the sample block to help students understand that sample is a subset of population.



Central Limit Theorem

Central limit theorem states given the distribution of a population under study with mean μ and variance σ^2 (regardless the shape of the original distribution), the distribution of the means of the random samples selected from the population approaches a normal distribution with mean μ and variance σ^2/n , as n , the sample size (i.e., the number of samples selected from the population) increases.

Central Limit Theorem

The distribution of all samples means of sample size n from a Normal Distribution (μ, σ^2) is a normally distributed with


Mean = μ

Variance = σ^2 / n

Standard Error = σ / \sqrt{n}

>>

Figure 27: A Screenshot of the Central Limit Theorem Main Page




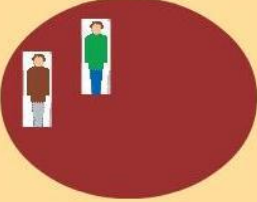
Central Limit Theorem

Population refers to the totality of the observations that are of interest to us in a particular study.

Sample is a subset of the population. In reality, it is usually impossible or impractical to measure all the observations in the population.

Therefore, a sample of the population is taken, data is collected from it, and inferences about the population are made based on the analysis of the sample data. A random sample of n observations is a sample with n observations, selected in such a way that every such sample of the population has the same probability of being selected.

Selecting participants randomly

Population
Sample

<<
>>

Figure 28: A Screenshot of the Page with Animation for Sample and Population

The third page introduces the concept of the sampling normal distribution. An animated curve is shown that represents a normally distributed curve of sample size n , as illustrated in Figure 29. Its parameters such as mean, variance and standard error are also explained. The Z transformation for a sampling normal distribution is derived in the next three pages. The last page of the central limit theorem concept has an animated sampling normal distribution curve along with a Z transformation formula, as shown in Figure 30.

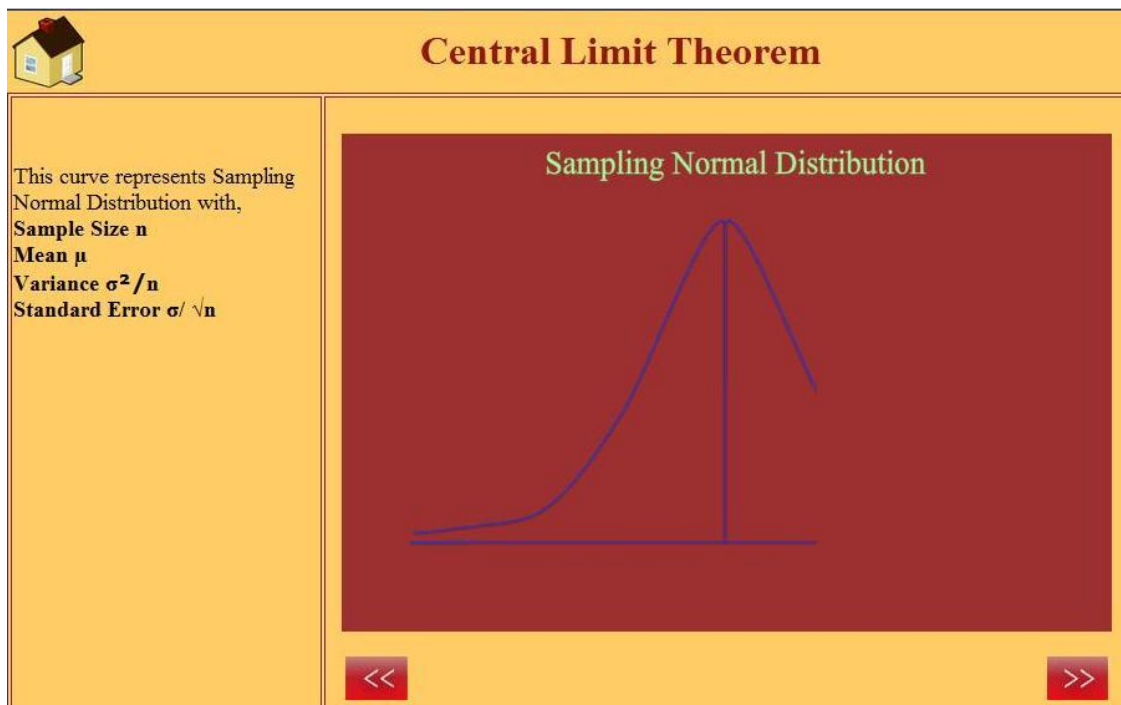


Figure 29: A Screenshot of the Page that shows Sampling Normal Distribution

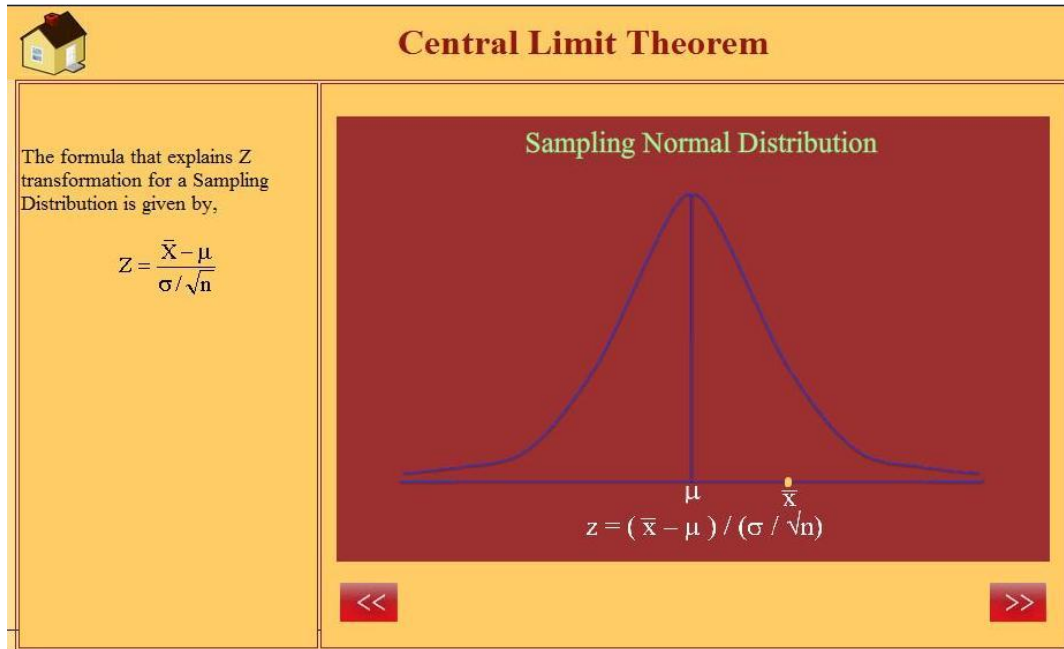


Figure 30: A Screenshot of Central Limit Theorem Concept that shows an Animated Curve

3.6 Tolerance Intervals and Confidence Intervals

3.6.1 Tolerance Interval

The first page of this concept module defines a tolerance interval and uses a figure of the normal distribution (shown in Figure 31) to illustrate the 95% tolerance interval of the data taken from a population under study. The next page includes a figure of a normal distribution showing the 95% tolerance interval covering the middle of the graph and the 5% level of significance divided on both sides graph, as shown in Figure 32.

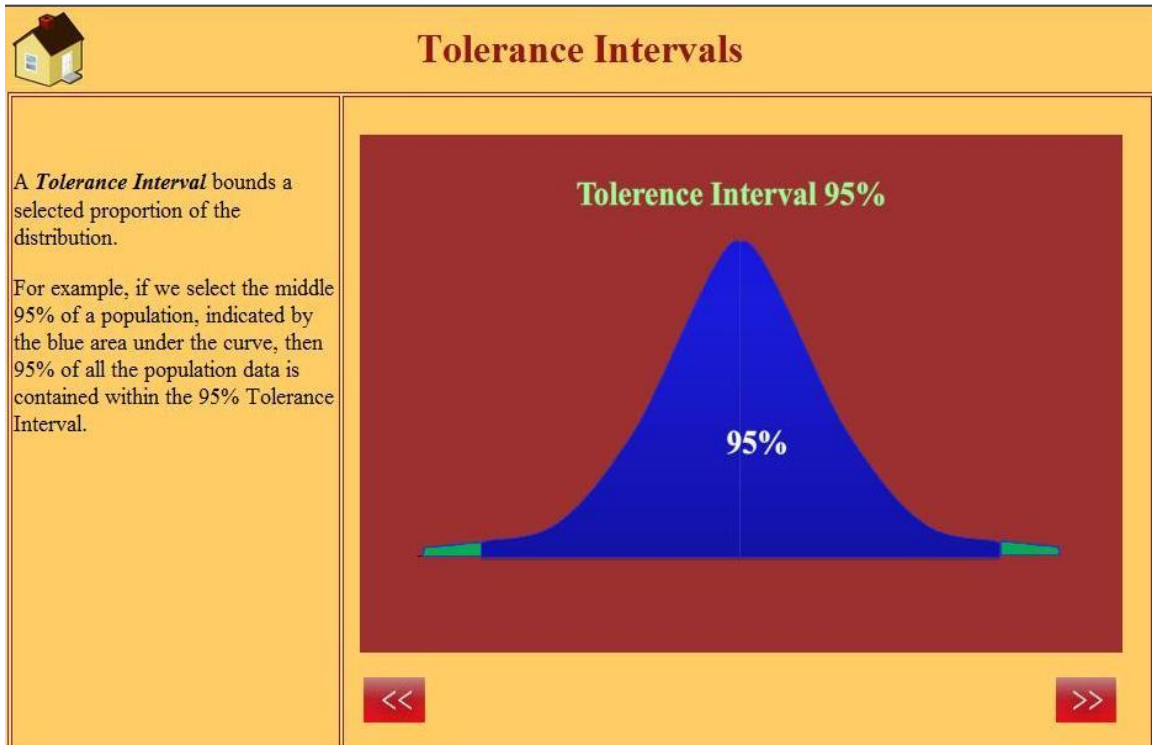


Figure 31: A Screenshot of the First Page of Tolerance Interval Tutorial

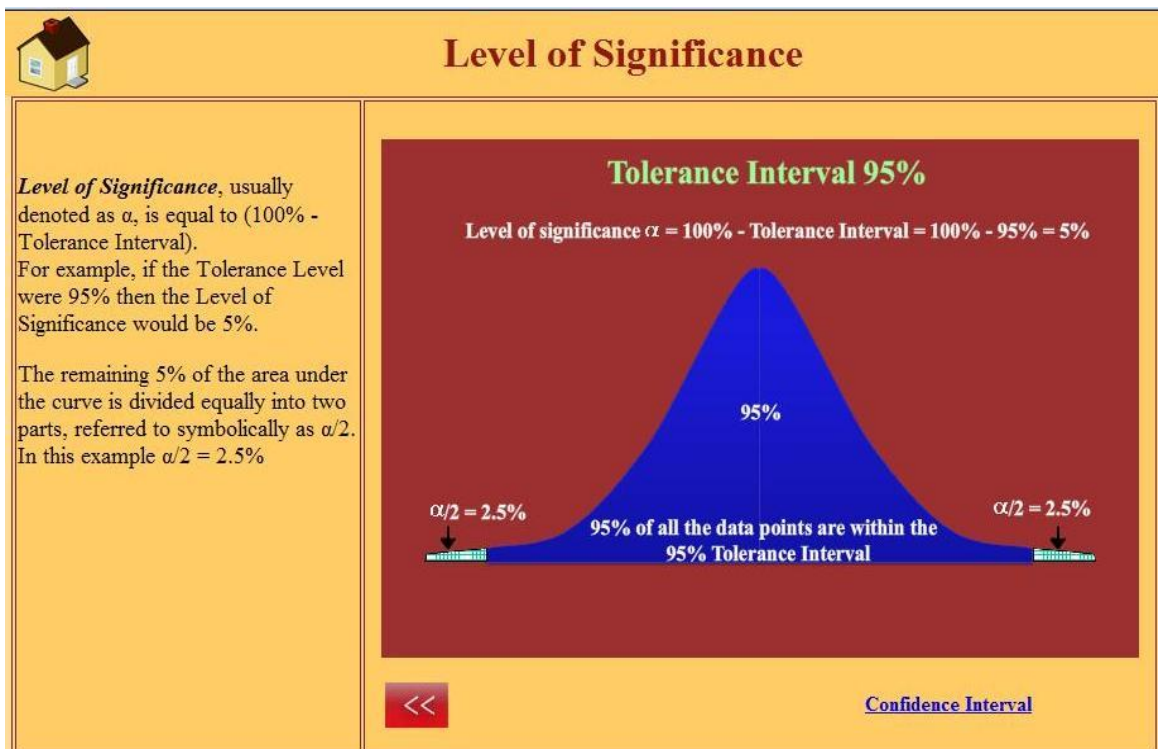
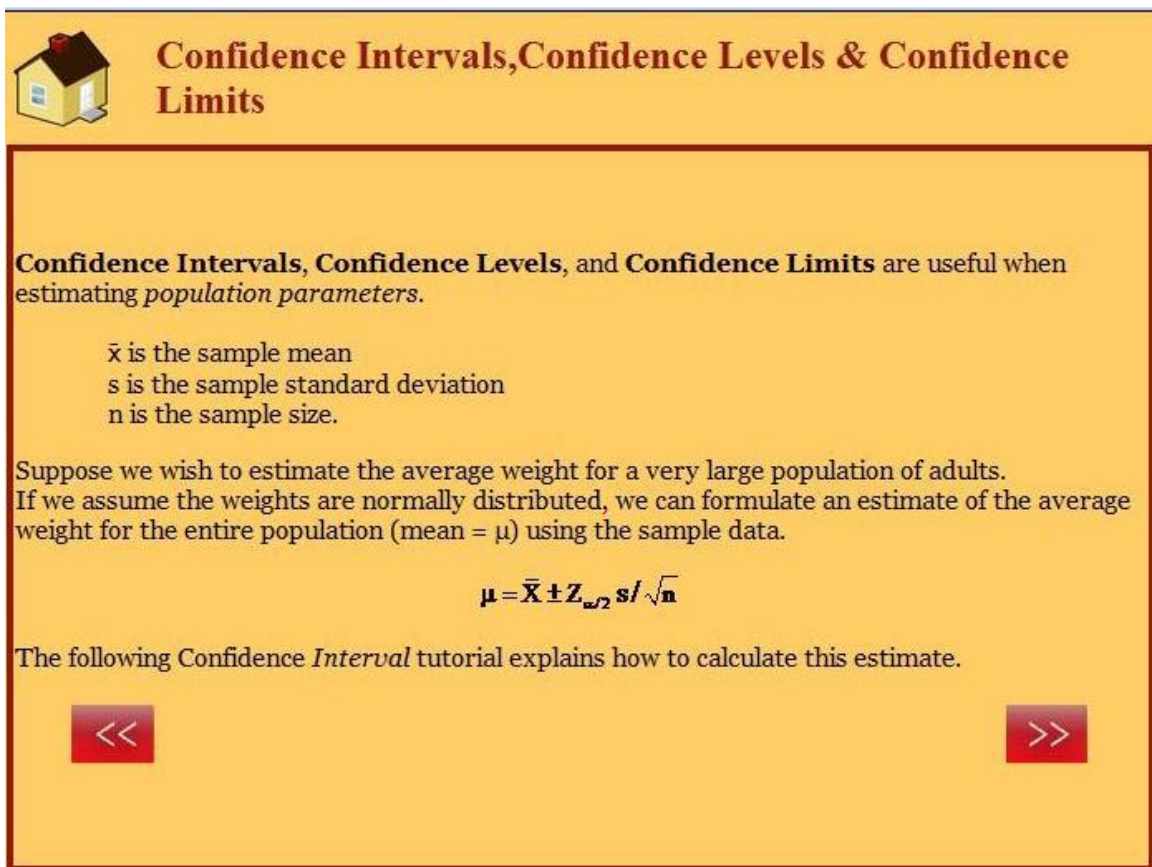



Figure 32: A Screenshot to Illustrate Level of Significance for 95% Tolerance Interval

3.6.2 Confidence Interval

The first page of this concept gives a brief overview of the confidence interval, confidence levels, and confidence limits, along with terms including sample mean, sample size, and sample standard deviation, as illustrated in Figure 33. Page two shows the formula for calculating a confidence interval for the population mean for a given level of significance α .



 **Confidence Intervals, Confidence Levels & Confidence Limits**

Confidence Intervals, Confidence Levels, and Confidence Limits are useful when estimating *population parameters*.

\bar{x} is the sample mean
 s is the sample standard deviation
 n is the sample size.

Suppose we wish to estimate the average weight for a very large population of adults. If we assume the weights are normally distributed, we can formulate an estimate of the average weight for the entire population (mean = μ) using the sample data.

$$\mu = \bar{X} \pm Z_{w/2} s / \sqrt{n}$$

The following *Confidence Interval* tutorial explains how to calculate this estimate.



 

Figure 33: A Screenshot of the First Page of the Concept of Confidence Intervals

IV. EXPERIMENT

A one-factor between-subject experiment was conducted to test two hypotheses regarding the advantages of the designed web-based course of statistics with graphics and animation: compared to traditional instruction methods, instructions with graphics and animations can enhance students' understanding of statistical concepts (1st hypothesis) and bring students greater satisfaction with the learning process (2nd hypothesis). The methodology employed in the experiment and results obtained are presented in sections 4.1 and 4.2, respectively.

4.1 Methodology

The methodology applied in this experiment is presented in the following order: participants, apparatus, procedure, and experiment design.

4.2 Participants

Twenty undergraduate engineering students, eighteen males and two females with ages between 18 and 25 were recruited for this experiment. Ten of the students were assigned to the group of the traditional instruction method, and the other ten to the group of the web-based course. They all met the criteria of having no knowledge of statistics

previously, being fluent in English; and having the capacity of conducting tasks on personal computers.

4.3 Apparatus

The teaching materials used in the group of traditional instruction were created using Microsoft PowerPoint. Some screenshots of the PPT based instruction method is shown in Appendix D. The web-based course with graphics and animations was created with Hyper Text Markup Language (HTML) and Adobe Flash Creative Suite 3.

Participants performed tasks on a personal computer equipped with a 17-inch LCD monitor, a standard US QWERTY keyboard, and a two-button mouse.

4.4 Procedure

The experiment took place in a sound-proof computer lab. Four sessions were administered in sequence for each participant during the experiment: pretest, training, formal tasks, and post-study. Each participant was first asked to fill out a pretest questionnaire (see Appendix A) to collect information of his/her age, gender, educational background, and familiarity with using personal computers and internet. Next, each participant was given a short tutorial of how to learn statistical concepts in the experiment, either through reading PowerPoint slides (in the control group) or via taking web-based lessons with graphics and animations (in the experimental group). After the training session, each participant took lessons of normal distribution, central limit theorem, and tolerance/confidence intervals using the assigned learning method and

answered nine multiple-choice questions regarding the lessons learned. The maximum allocated time for working on each question was two minutes. Finally, after each participant finished the formal tasks, he/she had to fill out a post-study questionnaire asking for his/her satisfaction with the learning process.

4.5 Independent Variable

The independent variable of the experiment was the type of instruction method – traditional instruction method versus web-based instruction with graphics and animations. With the traditional instruction method, participants were taught with lecture notes presented on Microsoft PowerPoint slides. Equivalent voice narrations were provided in both groups for explanation of the concepts taught.

4.5.1 Dependent Variables

The dependent variables of the experiment were the effectiveness of learning and satisfaction with the learning process for the first and second hypotheses, respectively. Nine multiple-choice test questions, with three questions for each statistical concept, were given to each participant. The number of questions that were correctly answered by each participant was recorded as the measure of the effectiveness of his/her learning. A seven-point Likert scale post-test satisfaction questionnaire with five questions was given to each participant, and his/her responses were recorded as his/her satisfaction with the learning process. The multiple-choice test questions and post-test satisfaction questionnaire can be found in Appendices B and C, respectively.

4.6 Statistical Analysis

One-sided two-sample t-tests were applied to analyze the experiment results to test the two hypotheses. Table 1 summarizes the experiment results of the number of correctly answered questions (out of nine points maximum) using the traditional and web-based instruction methods and participant's satisfaction with the two different learning processes. The numbers in parentheses are sample standard deviations. As shown in Table 1, compared to the traditional instruction method, the web-based course significantly ($p=0.037$) increased the effectiveness of participants' learning of the concepts, with a 29.8% increase in test scores and Cohen's $d = 0.91$. In addition, compared to the traditional instruction method, the web-based course significantly ($p=0.035$) increased the participants' satisfaction with the learning process, with a 19.2% increase in test scores and Cohen's $d = 1.02$.

Table 2: Experiment Results of the Number of Correctly Answered Questions and Participants' Satisfaction

Instruction Method	# of Correctly Answered Questions	Satisfaction
Traditional	4.7 (2.06)	4.7 (1.17)
Web-Based	6.1 (0.99)	5.6 (0.61)
Percentage improvement	29.8%	19.2%
p-value	0.037	0.035
Cohen's d	0.91	1.02

Figures 34 and 35 respectively illustrate the scatter plot of the total test scores and the scatter plot of participants' satisfaction in both the traditional and web-based instruction groups, where groups 1 and 2 respectively represent the traditional and web-

based instruction groups. From this figure we can see that there is a noticeable individual difference in the effectiveness and participants' satisfaction between the instruction methods.

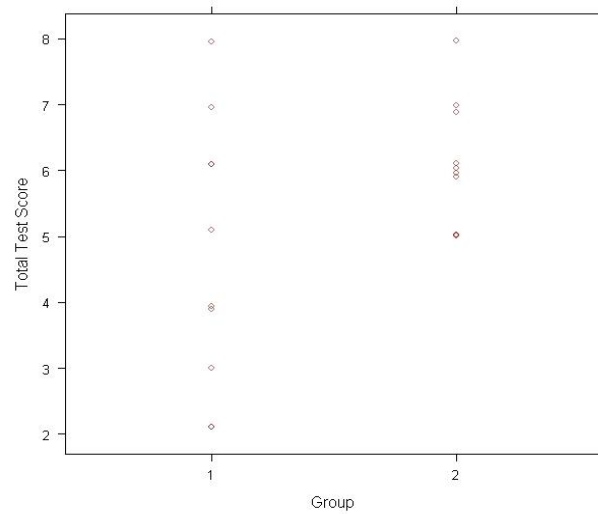


Figure 34: Scatter Plot of Total Test Scores for Traditional and Web-Based Instruction Groups (Groups 1 and 2 Represent Traditional and Web-Based Groups, Respectively)

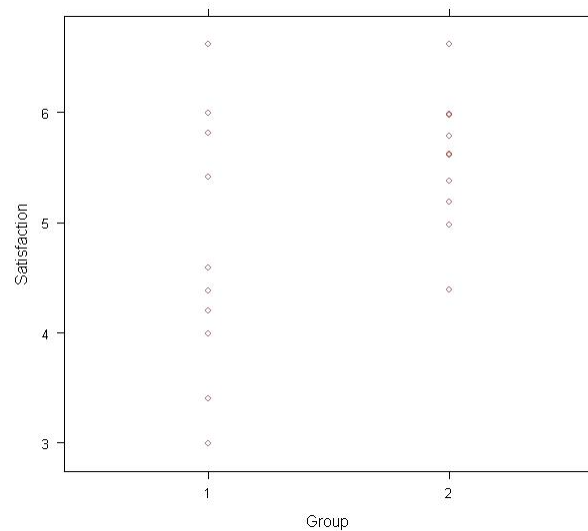


Figure 35: Scatter Plot of Participants' Satisfaction Rankings for Traditional and Web-Based Instruction Groups (Groups 1 and 2 Represent Traditional and Web-Based Groups, Respectively)

Table 2 shows the results of the number of correctly answered questions using the traditional and web-based instruction methods for each of the three statistical concepts learned. This table shows that the advantages of the web-based course over the traditional instruction method is the most significant for the module on tolerance/confidence intervals (42.86% increase, p -value = 0.062, and Cohen's d = 0.76), the most difficult among the three concepts taught in the experiment, followed by the normal distribution (31.58% increase, p -value = 0.082, and Cohen's d = 0.68), and the least for the central limit theorem (14.29% increase, p -value = 0.285, and Cohen's d = 0.27), the easiest concept taught in the experiment. This finding suggests that using the web-based course with graphics and animations is particularly effective in enhancing students' learning of difficult concepts.

Table 3: Experiment Results of the Number of Correctly Answered Questions for Each Statistical Concept

Instruction Method	Statistical Concepts		
	Central Limit Theorem	Normal Distribution	Tolerance/Confidence Intervals
Traditional	1.4 (0.70)	1.9 (1.20)	1.4 (0.97)
Web-Based	1.6 (0.84)	2.5 (0.53)	2.0 (0.67)
Percentage Improvement	14.29%	31.58%	42.86%
p -value	0.285	0.082	0.062
Cohen's d	0.27	0.68	0.76

V. CONCLUSIONS AND FUTURE RESEARCH

This chapter summarizes the findings and contributions in this study as well as its limitations. In addition, future research directions are discussed.

5.1 Findings and Contributions

During this project, web-based lessons with graphics and animations have been designed and developed for the purpose of helping students better understand statistical concepts. Graphics and animations are particularly capable of attracting learners' attention and facilitating their understanding of abstract concepts, both of which are important to teaching statistics. Students using any standard web browser can access these lessons.

Two hypotheses regarding the advantages of the web-based lessons with graphics and animations over traditional teaching of statistics have been derived, and an experiment was conducted to test the two hypotheses. Experiment results indicate that compared to traditional teaching of statistics, the designed web-based lessons can significantly improve the effectiveness of student learning of statistical concepts (by 29.8%) and enhance students' satisfaction with the learning process (by 19.2%).

5.2 Limitations of the Research

Participants in the experiment were young freshman engineering students who may not well represent the entire population of statistics students. There were two female participants in the experiment. This is a reflection of unbalanced proportions of female and male students in engineering. However, the effect of gender is not within the scope of this research.

The sample size of the experiment is relatively small – with only 10 participants in each group. This may explain the reason why the differences in the number of correctly answered questions between the two groups were not highly significant for individual statistical concepts.

Only three entry-level statistical concepts have been fully developed and tested due to the limited duration of the project. In addition, the experiment was conducted at a controlled computer lab. As a result, participants' performance in the experiment may not reflect what would happen in their normal learning environment.

5.3 Future Research

This research can be extended to test the results of web-based lessons by enrolling more engineering students with more diverse characteristics. More participants can be recruited to test the hypotheses.

In future web-based lessons that include data-driven animations can be designed. Such animations can improve the effectiveness of student learning because they allow students (users) to have more interactions with the lessons.

Web-based lessons of other statistical concepts, such as ANOVA and regression, can be developed. A glossary page can be included which explains the important elementary statistics concepts. The glossary page will be helpful to users who have no knowledge of statistics and also to those who need to refer to entry-level statistics concepts.

Furthermore, apart from teaching statistical concepts, examples of the applications of those concepts and different statistical tests conducted by researchers to analyze experimental results can also be included in the web-based lessons. The information can give users a better understanding of the importance of statistics and its practical applications.

Appendix A Pre-Experimental Questionnaire

We need to know a little about you in order to best interpret and analyze our experimental results. Please answer the following questions.

1. How old are you?

- ☐ 18-25
- ☐ 26-40
- ☐ 41-55
- ☐ Over 55

2. Are you:

- ☐ Male
- ☐ Female

3. How frequently do you use personal computers?

- ☐ Not at all
- ☐ Infrequently (only a few times monthly)
- ☐ Frequently (several times every week)
- ☐ Very frequently (daily)
- ☐ Other (please explain) _____

4. How frequently do you use internet in general?

- ☐ Not at all
- ☐ Infrequently (only a few times monthly)
- ☐ Frequently (several times every week)
- ☐ Very frequently (daily)

○ Other (please explain)_____

5. How frequently do you use Microsoft PowerPoint in general?

○ Not at all

○ Infrequently (only a few times monthly)

○ Frequently (several times every week)

○ Very frequently (daily)

○ Other (please explain)_____

Appendix B Post-study Questionnaire

Central Limit Theorem

1. Which of the following statements is true of sample and population
 - A. sample and population have the same meaning and can be used interchangeably
 - B. sample is a subset of population
 - C. population is a subset of sample
 - D. when conducting experiments, we usually collect data from the entire population for our study

2. You are interested in finding the number of the hours students at WSU spend in studying every week, so you randomly select/sample WSU students for your study. As the sample sizes increases, what happens to the distribution of the sample mean?
 - A. cannot be predicted
 - B. approaches to a normal distribution
 - C. its mean value approaches 0
 - D. its standard deviation approaches 0

3. Which of the following statements best describes the essence of the central limit theorem?
 - A. Mean = μ
 - B. Variance = σ
 - C. Standard Error of the Mean = σ^2/\sqrt{n}
 - D. all of the above

Normal Distribution

4. For a normal distribution, which of the following statements is always true?
- A. the standard normal distribution has a mean equal to 1
 - B. a normal distribution is symmetric about its standard deviation
 - C. the smaller the standard deviation the flatter the curve
 - D. the larger the standard deviation the flatter the curve
5. Suppose the random variable X is normally distributed with $\mu=0$ and $\sigma=1$, the area to the right of $x = 0$ is
- A. the same as the area to the left of $x = 0$
 - B. the same as the area to right of $x = 1$
 - C. the same as the area to the left of $x = 1$
 - D. cannot be decided
6. What is the formula for converting a non-standard normal distribution with mean μ and standard deviation σ to a standard normal distribution
- A. X/μ
 - B. X/σ
 - C. $(X - \mu)/\sigma$
 - D. impossible to convert

Confidence Interval

7. Given a Level of Significance = 5%, what is the probability that the calculated confidence interval will contain the true value of the population mean?
- A. 2.5 %
B. 5 %
C. 10 %
D. 95 %
8. A random sample of 30 households was selected as part of a study on electricity usage, and the number of kilowatt-hours (kWh) was recorded for each household in the sample for the March quarter of 2006. The average usage was found to be 400 kWh and standard deviation of the usage was 100 kWh.

Assuming monthly usage is normally distributed, which of the following expressions is correct for calculating a 95% confidence interval for the mean usage for March of 2006?

- A. $\left(400 - t_{0.025}(29) \cdot \frac{100}{\sqrt{30}}, 400 + t_{0.025}(29) \cdot \frac{100}{\sqrt{30}} \right)$
- B. $\left(400 - t_{0.025}(29) \cdot \frac{\sqrt{100}}{\sqrt{30}}, 400 + t_{0.025}(29) \cdot \frac{\sqrt{100}}{\sqrt{30}} \right)$
- C. $\left(100 - t_{0.025}(29) \cdot \frac{\sqrt{400}}{\sqrt{30}}, 400 + t_{0.025}(29) \cdot \frac{\sqrt{400}}{\sqrt{30}} \right)$
- D. $\left(100 - t_{0.025}(29) \cdot \frac{400}{\sqrt{30}}, 400 + t_{0.025}(29) \cdot \frac{400}{\sqrt{30}} \right)$

9. Using the same information as that in question 9, if you compare the 95% and 99% confidence intervals for the mean usage in the March quarter of 2006, which of the following statements is correct?
- A. the range of the 95% confidence interval is greater than the range of the 99% confidence interval
 - B. the range of the 95% confidence interval is smaller than the range of the 99% confidence interval
 - C. the range of the 95% confidence interval is the same as the range of the 99% confidence interval
 - D. cannot make definite conclusion about which range is greater

Appendix C Satisfaction Questionnaire

Please answer the following questions by indicating the number that best expresses your feelings and opinion.

1. My understanding of the statistical concepts studied in the experiment has been greatly enhanced

Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly
1	2	3	4	5	6	7

2. I am very satisfied with the worthwhile accomplishment I have received from this learning experience

Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly
1	2	3	4	5	6	7

3. I am very satisfied with my improvement in understanding of the statistical concepts learned in the experiment

Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly
1	2	3	4	5	6	7

4. Generally speaking, I am very satisfied with this learning experience

Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly
1	2	3	4	5	6	7

5. This learning experience is both educational and fun

Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly
1	2	3	4	5	6	7

Appendix D PPT-based statistics instruction

Figure 36 is a screenshot of the first slide of PPT based instruction method showing the statistical concepts that are explained during the tutorial and the navigation button used to come back to the first slide any time during the presentation.

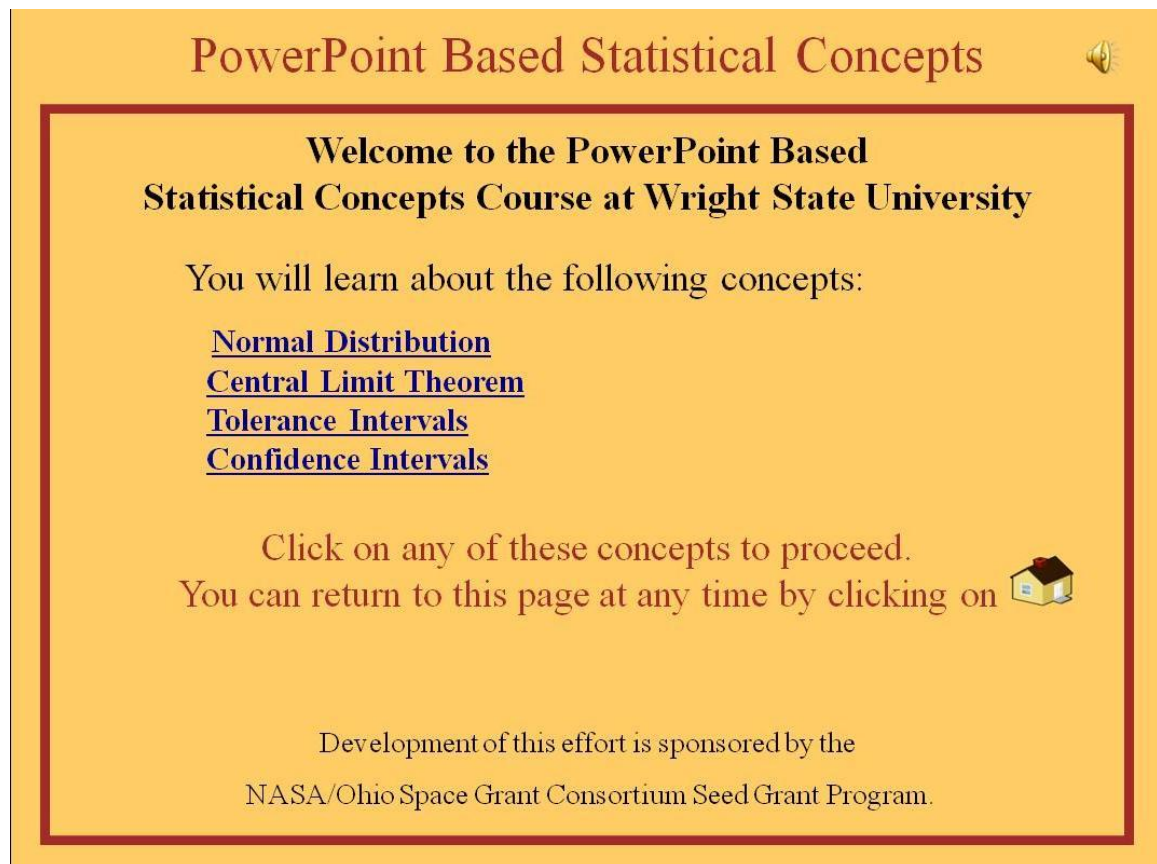
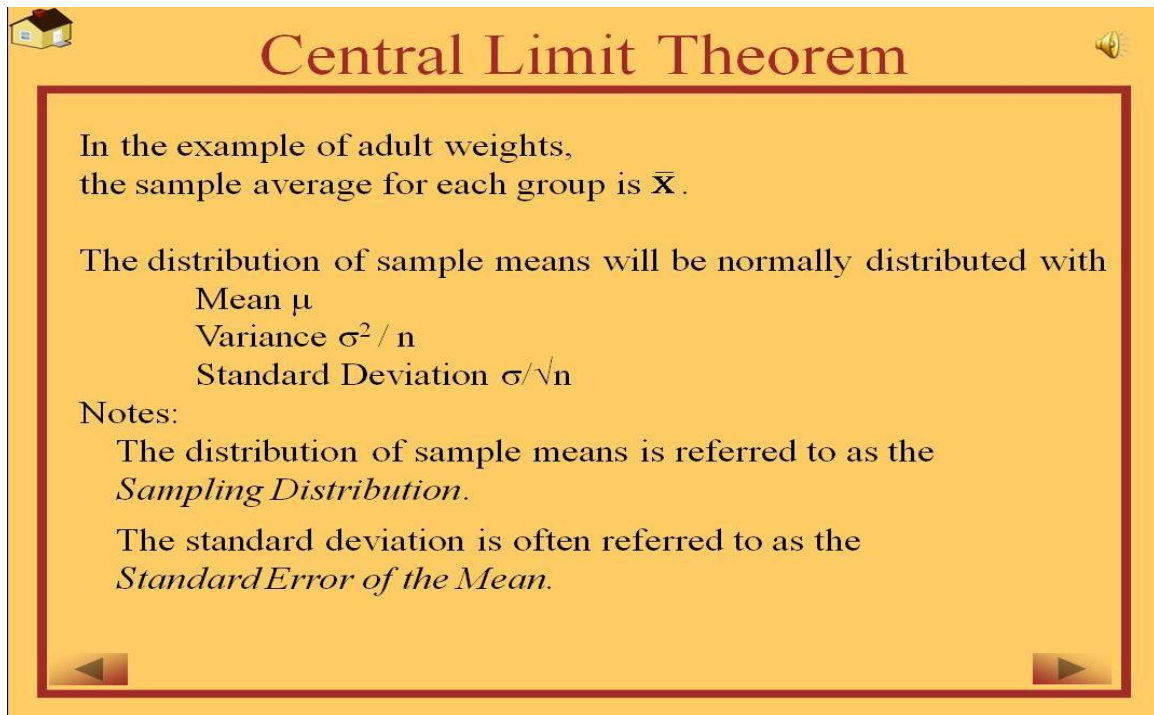


Figure 36: Screenshot of the first slide of PPT-based instruction of statistical concepts

Traditional instruction of statistics used text without graphics and animations.

Figure 37 is the screenshot of the slide that explains the concept of central limit theorem.



The screenshot shows a PowerPoint slide with a yellow background and a red border. The title 'Central Limit Theorem' is at the top center in a large, bold, red serif font. In the top left corner, there is a small icon of a house. In the top right corner, there is a small icon of a speaker. The main content is enclosed in a red rectangular frame. Inside this frame, the text is as follows:

In the example of adult weights,
the sample average for each group is \bar{X} .

The distribution of sample means will be normally distributed with

- Mean μ
- Variance σ^2 / n
- Standard Deviation σ / \sqrt{n}

Notes:

- The distribution of sample means is referred to as the *Sampling Distribution*.
- The standard deviation is often referred to as the *Standard Error of the Mean*.

At the bottom left and right corners of the red frame, there are small black triangular navigation icons.

Figure 37: Screenshot of the central limit theorem slide in a PPT-based instruction method

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